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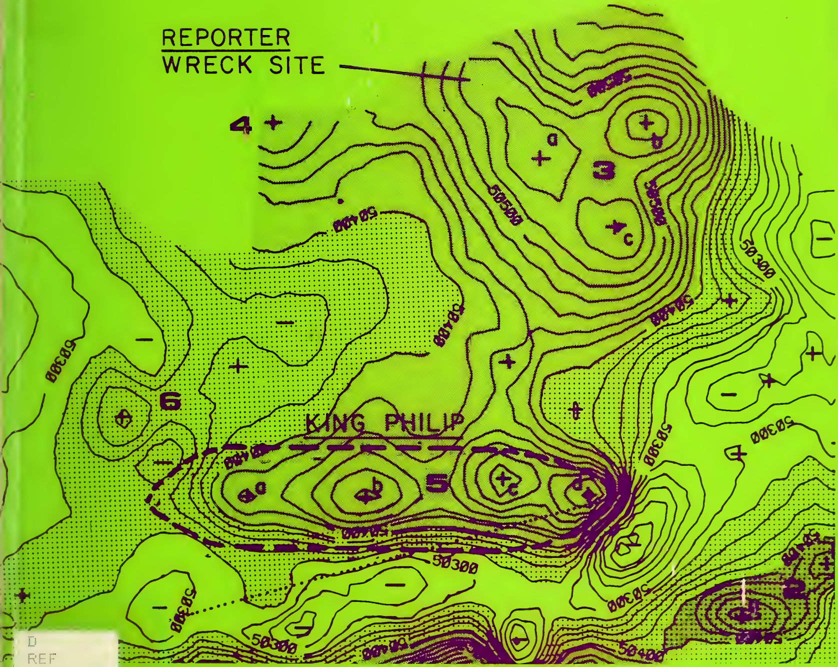

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CULTURAL RESOURCES MAGNETOMETER SURVEY AND TESTING GREAT HIGHWAY/OCEAN BEACH SEAWALL PROJECT, SAN FRANCISCO, CALIFORNIA

Prepared for:

San Francisco Clean Water Program
770 Golden Gate Avenue, 3rd Floor
San Francisco, California 94102

Prepared by:

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July 1988

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ABSTRACT

During the fall of 1987, archaeologists from Espey, Huston & Associates, Inc. (EH&A) conducted a terrestrial magnetic survey of a 2,770-foot section of National Park Service (NPS) property (part of the Golden Gate National Recreation Area (GGNRA)) along Ocean Beach in San Francisco, California. The objective of this study was to delineate the buried remains of historic shipwrecks prior to construction, by the San Francisco Clean Water Program, of the Great Highway/Ocean Beach seawall, between Noriega and Santiago streets. These investigations were required of the city by the GGNRA as one condition of Special Use Permit No. 4-8140-0870, granting permission for use of the beach as a construction zone, and were performed under Federal Antiquities Permit No. WR-1979-87-CA-2. This project assisted both the city and NPS in complying with Federal and State cultural resource regulatory requirements.

A magnetic contour map of the beach, generated on EH&A's Intergraph computer system, provided the basis for delineating areas of potential shipwreck scatter. The remains of two historic shipwrecks, the medium clipper King Philip (b. 1856) and the lumber schooner Reporter (b. 1876), both previously recorded within the project area but currently buried by beach sands, were magnetically verified. Two additional wreck sites have tentatively been located, one of which is believed to be the New Bedford-built whaling bark Atlantic (b. 1851). Wreckage of a fifth vessel, the steam schooner Aberdeen (b. 1899), may also occur scattered throughout the project area along what appears, from the magnetic contour map, to be the remains of an historic strandline.

In April of 1988, EH&A was contracted to conduct additional investigations on that portion of the suspected Atlantic wreck site which would be immediately impacted by seawall construction. Following removal of sand dunes and riprap, covering the eastern limit of the wreck site during the original study, a second magnetic survey was conducted. Mechanical test excavations revealed a small section of ship's keel, tentatively identified as belonging to the Atlantic. The location of this timber is believed to correspond to the winter strandline of 1886, the year in which the Atlantic wrecked. The results of these combined studies suggest that construction of the seawall should not result in impacts to articulated vessel elements in this area.

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ACKNOWLEDGEMENTS

Numerous persons have provided valuable support toward the successful completion of this project. The National Park Service staff was invaluable. Special notes of appreciation are extended to Mr. James Delgado of the National Maritime Initiative, to Mr. Marty Mayer of the Golden Gate National Recreation Area, and to Dr. Roger Kelly of the National Park Service for their assistance in providing necessary historic and environmental background data and logistical support. James Delgado and Larry Murphy are also recognized for the contribution which their previously published classification of environmentally exposed shipwrecks made to this report. My appreciation also goes to the National Park Service and to the National Maritime Museum of San Francisco for the use of the many historic photographs which are reproduced in this report.

Assistance in conducting the data analysis was provided by Mr. J. Barto Arnold III. Ms. Laura Jones, Ms. Laurel Smyth, Mr. Todd Hannahs and Mr. Greg Sundborg deserve a special thank you for their willingness to work long hours during the course of the field work. Much gratitude goes also to Mr. Rob Huggins and Mr. Ross Johnson and to their employer, EG&G Geometrics, for their patience and generosity in providing technical advice and assistance during the course of the project. Technical advice was also provided by Dr. John Weymouth, Dr. Bruce Bevin and Dr. Bob Nickel. Mr. Chuck Patterson and Mr. Gary Goldman deserve a special note of thanks for their combined computer wizardry during the contour mapping procedures. Editorial assistance was provided by Mr. Clell Bond and Mr. J. Barto Arnold III. Drafting was performed by Ms. Anne Woodall, Ms. Mary Fischer and Mr. David Kimmerling. The text of this report was authored by Bob Gearhart. Ms. Sara Pickus and her employer, the San Francisco Clean Water Program, are to be commended for their cooperation in sponsoring this endeavor.

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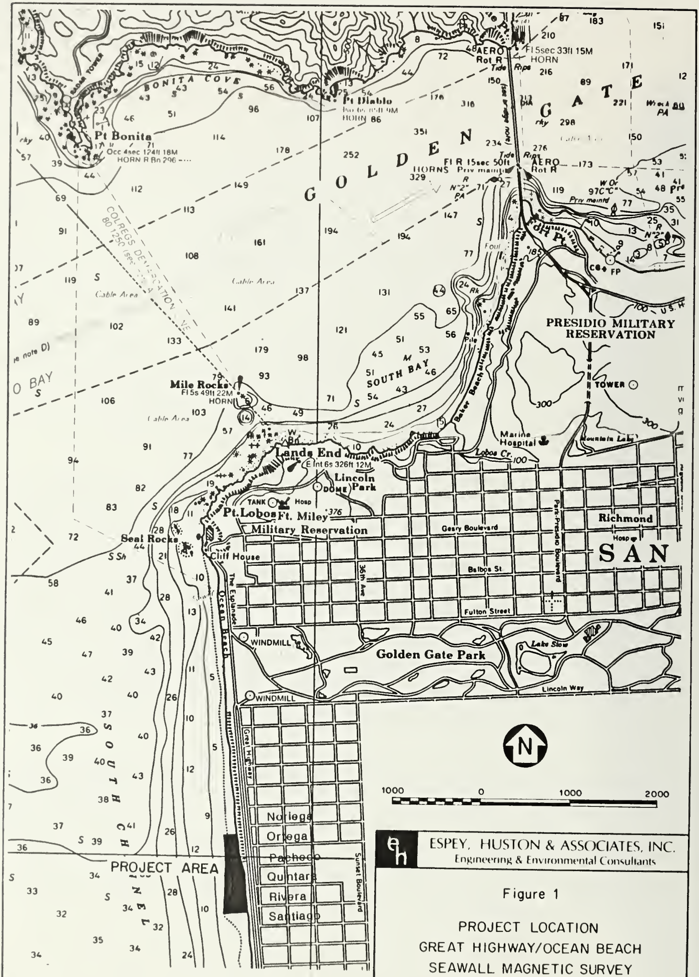
CHAPTER I
INTRODUCTION

The Great Highway/Ocean Beach Seawall Project (seawall) has been undertaken by the City and County of San Francisco's Clean Water Program (Clean Water) as a solution to an accelerating erosion problem along Ocean Beach between Noriega and Santiago streets (Figure 1). In recent years, wave action has increased along this section of the beach, resulting in severe beach loss and dune erosion during the winter storm season. Erosion of the sand dunes at the top of the beach, if unabated, threatens to undercut the Great Highway and to eventually expose the West Side Transport, a large wastewater tunnel underlying the highway. As a temporary solution, the city covered the dune face with riprap, composed primarily of concrete rubble and stone (Figure 2). In need of a more permanent solution, Clean Water commenced with plans for a concrete seawall (currently under construction), similar to the existing Esplanade. The seawall is to be constructed entirely upon city property; however, construction activities will unavoidably impact portions of Ocean Beach which is owned by the National Park Service (NPS) and managed as part of the Golden Gate National Recreation Area (GGNRA).

During the course of construction, an area of NPS property, approximately 40 feet wide and 1,800 feet long, will be affected by excavation for the placement of seawall footings, by the removal of rubble from the adjacent dune face, and as a contractor's work area. The GGNRA, a division of NPS, authorized the use of this area by Clean Water under the conditions of Special Use Permit No. 4-8140-0870. A major condition of this permit stipulated that, prior to beginning construction, Clean Water obtain the services of a qualified archaeologist to conduct an Historical Cultural Resources Survey. The goals of this survey would be to locate historic cultural resources within the project area; to judge their significance; to determine the project's probable effects on these resources; and to propose measures to mitigate these effects. The project area for the cultural resources survey is defined under the terms of the permit as the dune and beach area west of the NPS property line (referred to as the GGNRA line) between Noriega and Santiago streets and extending westward to the line of the mean lower low tide.

The archaeological/historic potential of the project area has been well demonstrated. Historic records maintained by the archaeological staff of GGNRA indicate the presence of as many as 26 shipwrecks along Ocean Beach (Delgado 1987). The remains of two vessels, the King Philip and the Reporter, were positively identified within the survey area in 1983 when their remains were exposed by erosion. Wreckage from at least two additional ships, the whaling bark Atlantic and the steam schooner Aberdeen, is also believed to be present within the project area. A summary of the historic resources present or suspected within the area is provided in Chapter III.



ESPEY, HUSTON & ASSOCIATES, INC.
Engineering & Environmental Consultants

Figure 1

PROJECT LOCATION
GREAT HIGHWAY/OCEAN BEACH
SEAWALL MAGNETIC SURVEY

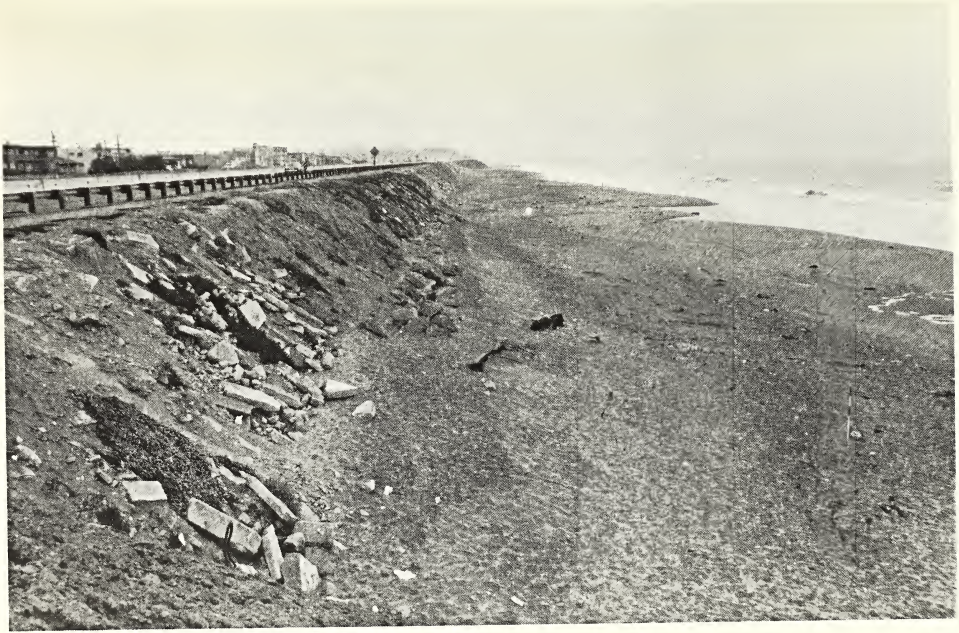


Figure 2. Overview of project area; looking south from top of Ortega Street sand pile. Rivera Street sand pile, near horizon, is approximate southern limit of survey.

During the months of September and October, 1987, archaeologists from Espey, Huston & Associates, Inc. (EH&A) of Austin, Texas, conducted a terrestrial magnetometer survey of the project area, a 2,770-foot section of Ocean Beach (Figure 1). As stated above, the objectives of this study were to delineate the buried remains of historic shipwrecks on NPS property and to determine whether these remains might be impacted by construction of the seawall. A magnetic contour map of the project area (Figure 3a-d) was generated from the survey data on EH&A's Intergraph computer system. The results verified the locations of the King Philip and Reporter wrecks and indicated several other areas which appeared to contain the buried remains of historic shipwrecks or shipwreck debris, including one area believed to contain the remains of the Atlantic. A detailed discussion of the magnetometer survey and its results, including a thorough interpretation of Figure 3, is provided below in chapters IV and V.

Upon submission and review of the draft survey report (chapters II through V of this document) in December 1987, archaeological staff from the State Historic Preservation Office (SHPO) concurred with the NPS staff in recommending additional investigations on a portion of the suspected Atlantic wreck site to be impacted by seawall construction. In April of 1988, EH&A returned to Ocean Beach in order to verify whether or not historically significant wreckage would be impacted in this area (Figure 3c; Area D). This phase of the investigations, summarized in Chapter VI, included an additional magnetometer survey of a small area, followed by hydraulic probing and mechanical test excavations. The results indicate that small, isolated elements of wreckage occur within the zone to be impacted by seawall construction; however, the potential for encountering articulated portions of a vessel within this area are considered low. A short section of keel from a copper-sheathed vessel was encountered during archaeological test excavations and has been tentatively identified as coming from the Atlantic.

Figure 3a

A MAGNETIC CONTOUR MAP OF THE GREAT HIGHWAY/OCEAN BEACH SEAWALL PROJECT

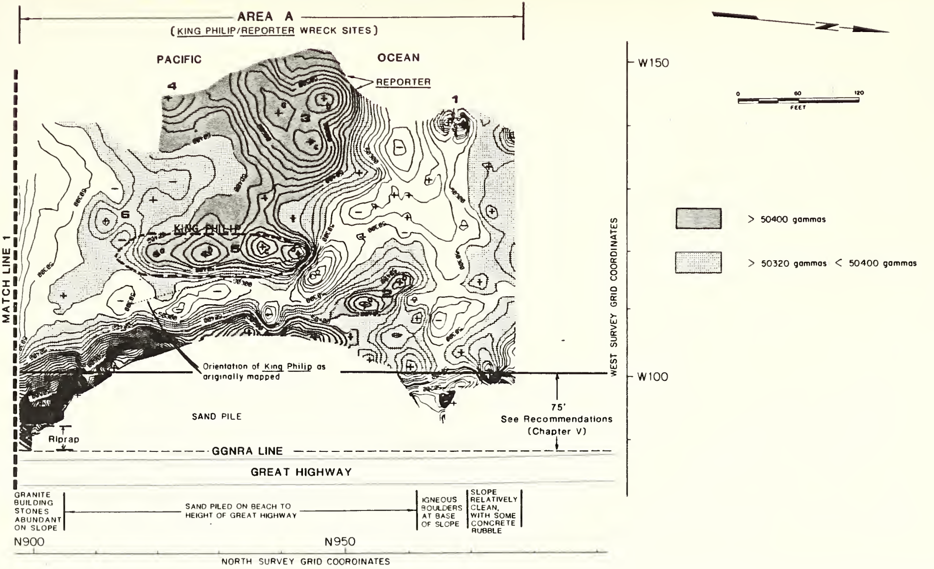

AREA A
(KING PHILIP/REPORTER WRECK SITES)
PACIFIC
OCEAN
REPORTER
1
2
3
4
5
6
KING PHILIP
Orientation of King Philip as originally mapped
SAND PILE
Riprap
GGNRA LINE
GREAT HIGHWAY
75'
See Recommendations (Chapter V)
MATCH LINE 1
GRANITE BUILDING STONES ABUNDANT ON SLOPE
SAND PILED ON BEACH TO HEIGHT OF GREAT HIGHWAY
IGNEOUS BOULDERS AT BASE OF SLOPE
SLOPE RELATIVELY CLEAN, WITH SOME CONCRETE RUBBLE
N900
N950
NORTH SURVEY GRID COORDINATES
W150
W100
WEST SURVEY GRID COORDINATES
N
0
60
120
FEET
> 50400 gammas
> 50320 gammas < 50400 gammas

Figure 3b

A MAGNETIC CONTOUR MAP OF THE GREAT HIGHWAY OCEAN BEACH SEAWALL PROJECT

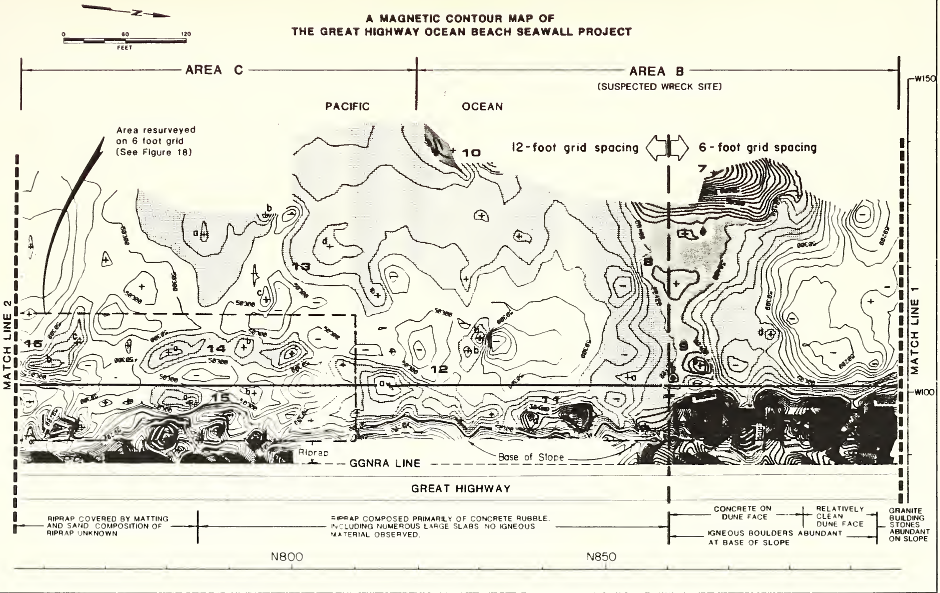

N
0
60
120
FEET
AREA C
AREA B
(SUSPECTED WRECK SITE)
W150
W100
PACIFIC
OCEAN
Area resurveyed on 6 foot grid (See Figure 18)
12-foot grid spacing
6-foot grid spacing
7
8
9
10
12
13
14
15
16
a
b
c
d
58300
MATCH LINE 2
MATCH LINE 1
Riprap
GGNRA LINE
Base of Slope
GREAT HIGHWAY
RIPRAP COVERED BY MATTING AND SAND. COMPOSITION OF RIPRAP UNKNOWN
RIPRAP COMPOSED PRIMARILY OF CONCRETE RUBBLE. INCLUDING NUMEROUS LARGE SLABS. NO IGNEOUS MATERIAL OBSERVED.
CONCRETE ON DUNE FACE
RELATIVELY CLEAN DUNE FACE
GRANITE BUILDING STONES ABUNDANT ON SLOPE
IGNEOUS BOULDERS ABUNDANT AT BASE OF SLOPE
N800
N850

Figure 3c

A MAGNETIC CONTOUR MAP OF THE GREAT HIGHWAY/OCEAN BEACH SEAWALL PROJECT

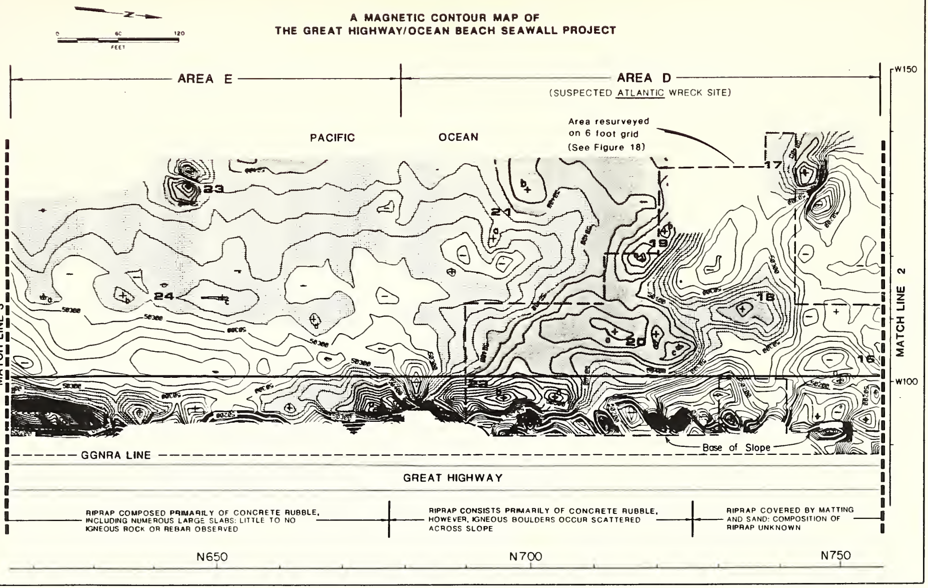
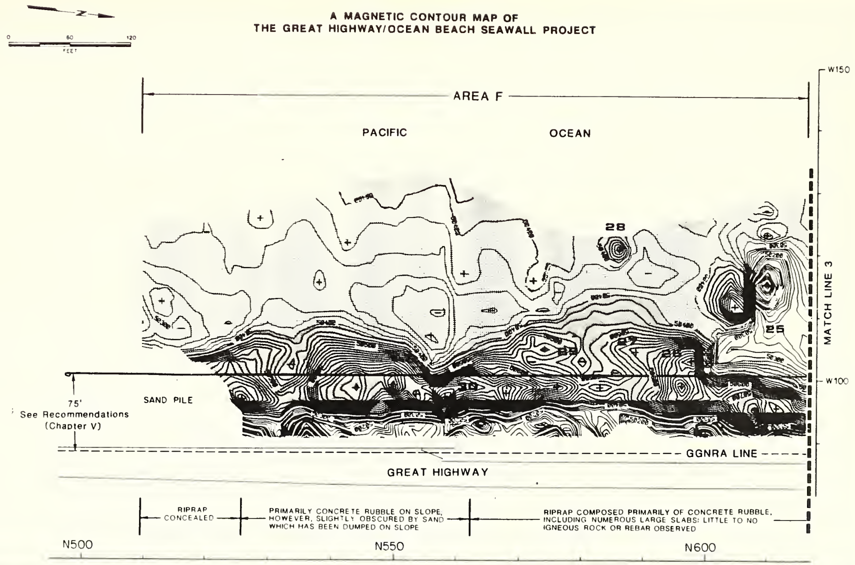

N
0
60
120
FEET
AREA E
AREA D
(SUSPECTED ATLANTIC WRECK SITE)
Area resurveyed
on 6 foot grid
(See Figure 18)
PACIFIC
OCEAN
W150
W100
MATCH LINE 2
MATCH LINE 3
15
16
17
18
19
20
21
22
23
24
50300
50200
Base of Slope
GGNRA LINE
GREAT HIGHWAY
RIPRAP COMPOSED PRIMARILY OF CONCRETE RUBBLE, INCLUDING NUMEROUS LARGE SLABS: LITTLE TO NO IGNEOUS ROCK OR REBAR OBSERVED
RIPRAP CONSISTS PRIMARILY OF CONCRETE RUBBLE, HOWEVER, IGNEOUS BOULDERS OCCUR SCATTERED ACROSS SLOPE
RIPRAP COVERED BY MATTING AND SAND: COMPOSITION OF RIPRAP UNKNOWN
N650
N700
N750

Figure 3d

A MAGNETIC CONTOUR MAP OF
THE GREAT HIGHWAY/OCEAN BEACH SEAWALL PROJECT


N
0
60
120
FEET
AREA F
PACIFIC
OCEAN
W150
W100
MATCH LINE 3
28
25
26
27
29
30
SAND PILE
75'
See Recommendations
(Chapter V)
GGNRA LINE
GREAT HIGHWAY
RIPRAP CONCEALED
PRIMARILY CONCRETE RUBBLE ON SLOPE, HOWEVER, SLIGHTLY OBSCURED BY SAND WHICH HAS BEEN DUMPED ON SLOPE
RIPRAP COMPOSED PRIMARILY OF CONCRETE RUBBLE, INCLUDING NUMEROUS LARGE SLABS; LITTLE TO NO IGNEOUS ROCK OR REBAR OBSERVED
N500
N550
N600

CHAPTER II
ENVIRONMENTAL FACTORS AFFECTING WRECK SITE FORMATION

The geographic location of Ocean Beach downwind from the Golden Gate (Figure 1), in combination with sea and weather patterns along this stretch of coast, create a unique set of circumstances which seem conducive to vessel loss by grounding, especially during the winter season. Ocean Beach is located from 0.5 to 3 miles south of Point Lobos, the southern headland of the Golden Gate. Due to its unique position, an extremely large number of vessels have sailed or steamed past Ocean Beach in historic times. A combination of environmental factors, including wind and current direction, seasonal fluctuation in wave height, and bottom characteristics, have contributed to the demise of at least 26 of these vessels in historic times (Delgado 1987).

A thorough knowledge of local environmental conditions is a prerequisite to understanding why so many vessels came ashore on Ocean Beach. Additionally, this information provides a basis for understanding and predicting the manner in which wreckage may have dispersed across the beach during a particular wreck event. The latter information can be directly applied to the interpretation of magnetic anomaly patterns observed on Ocean Beach. An understanding of environmental conditions is also essential for assessing site preservation potential. The remainder of this chapter discusses the interplay between locally prevailing environmental conditions as they affect vessel loss, wreckage dispersal patterns, and preservation of wreck sites on Ocean Beach.

Vessel Loss

Historic accounts of wrecks which have occurred on Ocean Beach attribute vessel groundings to a number of recurrent and interrelated environmental factors. Foremost among these are wind direction, wind loss, current direction, tidal change, wave intensity, bottom characteristics, and fog.In general, it can be said that environmental conditions are significantly more severe during the winter months and, therefore, more conducive to vessel loss than during the summer months.

The prevailing wind direction along Ocean Beach is from the northwest. Winds from this direction also tend to be the strongest, although wind velocities generally range from 4 to 15 miles per hour. The windiest months (sustained winds) are March through June, with the highest incidence of wind storms being from December through May (U.S. Army Corps of Engineers 1979).

The prevailing direction of wave attack, both of deep-sea swells and of local seas, is also from the northwest. The configuration of the San Francisco bar, five miles west of the Golden Gate, currently tends to deflect much of the wave energy away from the northern portion of Ocean Beach; however, from Noriega Street southward, wave energy is higher, resulting in a severe erosional problem between Noriega and Santiago streets. Seasonal variation in wave height may be a major factor in the apparent tendency toward vessel loss during the winter season. Seymour, Castel and Thomas (1987:64) reported significantly higher deep-sea waves at the Farallon Islands for the months of January through March, than for July through September.

Tides along Ocean Beach vary, on the average, from a mean high tide of 5.20 feet to a mean low tide of 1.20 feet, with tidal extremes being 8.50 feet and -2.50 feet. Direction of the longshore current varies with the tides. During flood tide, the current trends toward the north at a maximum velocity of 1.0 knot, while during an ebb tide, the current flows southward at a maximum velocity of 1.3 knots. The combined effect of wave attack and tidal currents in the vicinity of the project area is a net littoral transport of sediment to the south.

In order to better illustrate the interplay of environmental factors as they contribute to vessel loss, an hypothetical scenario of a wreck event at Ocean Beach is provided below. This scenario is based upon the combined historic accounts of the King Philip and Atlantic wrecks. These events are described in more detail and referenced appropriately in Chapter III. Those details which serve to emphasize the role of environmental factors in site formation processes have been generalized below. This account is not necessarily typical of wrecks which have occurred at Ocean Beach, although it may be characteristic of wrecks involving outbound vessels. Verification of this hypothesis would require additional historic research.

It seems to have been a common practice for outbound sailing vessels to depart San Francisco Bay on an ebb tide. This was, no doubt, due to the fact that the normal tidal current through the Golden Gate is four knots (Bascom 1980:102). Despite the outward-flowing current, sailing vessels were towed by tugs through the Golden Gate to a point near the San Francisco bar, where they were released. Once under power of sail, these vessels were at the mercy of wind and currents. It could generally be expected that a northwest wind would be blowing as sailing vessels began their first tack. Should the wind be blowing from the west, however, it became necessary, at least in the case of the Atlantic, to make the first tack toward the south, in order to make enough headway to clear the Seal Rocks (Figure 1).

A southerly tack, in combination with a southerly flowing ebb tide current, would carry a vessel to a point offshore from Ocean Beach. Under normal circumstances, this would not have been a problem, as the outgoing tide would also assist the ship in its efforts to gain headway out to sea. If the winds were light, however, little headway was made, and the ship lingered uncomfortably close to the beach (within three miles or so). A sudden loss of wind at this point would leave a vessel helplessly adrift in the current were it not for the ship's anchors. Should the tide turn, as sometimes happened during the lengthy ordeal of clearing the bar, the already precarious position of the vessel was worsened by the incoming tidal flow.

Seeing the danger of the situation, the ship's captain would be quick to drop an anchor off of the bow and wait for a favorable breeze. During months of low wave energy, this tactic might work every time; however, such was not always the case during the winter months. Due to the lack of a good anchor hold on the hard, sandy bottom, the larger winter waves were often capable, on a windless day, of pushing a vessel toward the beach, with both anchors dragging. Such was the fate of both the King Philip and the Atlantic.

Wreckage Dispersal Patterns

Just as the interplay of environmental factors could determine the fate of a vessel outbound from San Francisco Bay, the ultimate disposition of a wrecked vessel was also determined, to a large extent, by the forces of nature. Wreck site characteristics, such as hull orientation and wreckage dispersal patterns, were shaped primarily by the wreck environment. A thorough understanding of these patterns and of the forces that cause them is invaluable to the accurate interpretion of magnetometer survey data. This knowledge can be an especially useful interpretive tool when used in combination with historic documentation of specific wreck events, as was possible with this study.

Characteristics of wreckage dispersal which can be affected by environmental variables include: the orientation of the hull or of largely intact hull elements; the degree to which a vessel breaks apart in the surf; and the directions and areal extent of wreckage scatter from the point of initial hull breakup. Environmental factors at the time of the wreck which can affect these variables include: direction of wave attack, height of breaking waves, tidal stage, and direction of tidal currents. Knowledge of environmental conditions at the time of a wreck is essential to predicting the final disposition of the wreckage; however, the physical condition of a vessel, as well as cultural factors, such as the judgement of a ship's captain, also play a large part in determining the manner in which a vessel wrecks. The interplay of cultural and environmental factors in determining wreck site patterning is discussed in more detail in the section of Chapter IV entitled "Anomaly Pattern Recognition".

Site Preservation

Once the remains of a ship have been deposited on the beach, they are generally subjected to some form of salvage operations, not only to retrieve the cargo, but to obtain the ship's fittings and any other material of potential value. What remains of a vessel following salvage is generally left exposed to the elements for some time. The remains of the King Philip, for example, are known to have been exposed for at least 24 years (see Chapter III). During this period of exposure, wooden and iron elements of a vessel are prone to rapid decomposition; however, once buried in an anaerobic environment, such as saturated beach sands, vessel elements may preserve for an indefinite period. Thus a wooden-hulled vessel which wrecked in the mid-nineteenth century and became quickly buried may be expected to remain in a relatively stable state of preservation today. Subsequent exposure of vessel remains, however, may have a serious detrimental effect upon their state of preservation, depending upon the duration and degree of exposure.

The exposure and subsequent deterioration of vessel elements in the survey area are a distinct possibility, as a seasonal cycle of large-scale beach erosion and accretion has been well-documented for Ocean Beach, most recently by studies associated with the Westside Transport project. The dynamic nature of Ocean Beach requires that some consideration be given to shoreline changes during historic times. In the event that significant shoreline alterations have occurred in the survey area since the beginning of a maritime tradition along the California coast, it would not be unreasonable to expect shipwrecks well beneath the modern dune line or far out into the surf zone, rather than beneath the modern beach.

Olmsted and Olmsted (1979) conducted a study of historic shoreline changes along Ocean Beach, in which they overlaid historic maps from various periods in an attempt to document significant long-term shoreline changes. Their results indicated that, while rather large fluctuations have occurred in the location of the shoreline at various points along the beach, none of these trends has been beyond the range of short-term changes which have been known to occur. Lateral shoreline migrations of as much as 50 to 100 feet have been documented within a single year. Additionally, it is known from past elevation profiles recorded along Ocean Beach that vertical fluctuations of several feet are not uncommon on a seasonal basis. The results of their study do not, however, provide an accurate basis for predicting the eastern or western limits of historic wrecks on the beach.

CHAPTER III
HISTORICAL AND ARCHAEOLOGICAL BACKGROUND

As stressed in Chapter II, Ocean Beach is located in a unique setting which has promoted the accumulation of a high density of historic shipwrecks in comparison to most beach environments. Historic research conducted by the staffs of both the National Maritime Initiative and the GGNRA, has identified at least 26 shipwrecks along Ocean Beach (Delgado 1987), including two in the project area: the medium clipper ship, King Philip, and the lumber schooner, Reporter. The remains of at least two other vessels, the New Bedford whaling bark, Atlantic, and the steam schooner, Aberdeen, are also suspected, on the basis of historical documentation, to be present in the project area. The presence of the King Philip was verified by the examination of exposed wreckage during the spring of 1983 and 1984. Wreckage from the Reporter was tentatively identified at that time. The results of the current study fit so closely with historic accounts of the Reporter and Atlantic wreck events as to practically confirm the presence of those vessels within the project area as well. Although wreckage from the Aberdeen has not been physically verified, the likelihood is high for the presence of at least a portion of its scattered remains.

A brief historical summary is provided below for each of these vessels. Whenever possible, pertinent facts regarding environmental conditions at the time of a wreck and/or regarding vessel construction materials have been gleaned from contemporary newspaper accounts or other historic documents. Information of this type, including descriptions of weather and sea conditions at the time of a wreck, comments regarding both the physical condition of a vessel and the actions of a crew during their attempts to prevent a wreck, and eye-witness accounts or photographs, can provide clues as to the possible source of magnetic anomaly patterns and has been integrated into the interpretation of anomaly patterns mapped along Ocean Beach during this survey (Chapter V). A thorough discussion of ways in which environmental variables may contribute to or affect wreck site formation is provided in Chapter II.

Known or Suspected Shipwrecks

King Philip

The King Philip was constructed in 1856 at the shipyard of D. Weymouth in Alna, Maine, for W. T. Glidden. Launched in November of 1856, she measured 182 feet long; 36 feet, 3 inches abeam; 24 feet deep; and had a draft of 20 feet. She was constructed of white oak and hackmatack with iron and copper fastenings (American Lloyds 1861). Originally sheathed with copper, she was resheathed in 1860, 1867 and 1871 (Delgado 1985a). The latter two times, she was sheathed in yellow metal, an alloy of copper, zinc and tin. The King Philip was built with two decks, a square stern, and a figurehead at the bow (Delgado 1985a). At 1,194 tons, she is believed to be the largest vessel built in Alna during the period from 1811 to 1896 (Fairburn 1945 to 1955). Although the King Philip was advertised by her owners as a "first-class Clipper ship", she was actually constructed along the lines of a medium-clipper, known also as a down-easter. The term down-easter has its origins in the fact that this form of vessel was commonly constructed in the "down east" states (MacGregor 1979:134).

The significance of the King Philip to maritime history lies primarily in the fact that she was constructed during a transitional period in American ship building. The late 1850s and early 1860s saw a decline in the popularity of the clipper ship in favor of the medium-clipper or down-easter. The King Philip, constructed in 1856, had a hull design similar to that of the medium-clippers at a time when clipper ships were still the preference of the American shipbuilding industry for merchant vessels. The King Philip, therefore, is believed to represent one of the earliest examples of the medium-clippers, a vessel type which came to be the backbone of the American merchant fleet from 1870 to 1890. The significance of the King Philip is increased by the fact that hers are the most-intact environmentally exposed (although currently buried) shipwreck remains known to exist on the California coast. As such, they can provide not only a wealth of data on construction techniques of the period, but also important information regarding site formation processes in exposed beach environments.

In order to better understand the significance of the King Philip and its position in history, one must understand the nature of and reasons for the transition from clipper ship to medium-clipper. The clipper ship was, without a doubt, the fastest sailing vessel in the American merchant fleet; however, this speed was attained at the sacrifice of carrying capacity and hull strength. Chapelle (1935:284) decribes the clipper ship's development as a culmination of the "mania for speed [which] had slowly been infecting American seamen and shipbuilders since 1790." High profits associated with California's boom economy, in combination with the highly publicized and romantized spirit of competition for fast passage, allowed the clipper ship to continue in popularity longer than economics, alone, would have dictated. Chapelle attributed the clipper ship's "remarkably short career" (approximately 1846 to 1859) to its relatively low carrying capacity, and extremely high operating costs. In addition to trading off cargo capacity for speed, he pointed out that "the hard driving, necessary to get speed out of these ships, required large crews and, also, caused loss of spars, sails and gear, as well as straining the weakly built wooden hulls" (Chapelle 1935:286).

The design of the medium-clipper, or down-easter, was, according to Chapelle, a "revival" of the later packet-ship designs which had immediately preceded and overlapped with the early development of the clipper ship; however, "the medium-clippers were larger and better built than the...packets and, also, had many of the improved fittings on deck and aloft that had been developed in the clippers" (1935:286-287). Design problems inherent with combining large size and heavy cargo capacity in the medium clippers were apparently alleviated through an improvement in hull design, "diagonal strapping", applied by American builders to some of the later clipper ships (Chapelle 1935:286). This technique greatly increased the longitudinal strength of the hull.

In comparison to the clipper ship design, the medium-clipper was less sharp in its lines, broader in the beam, fuller-ended than later models of the clipper ship, and had a rather flat floor extending well fore and aft, in order to increase cargo capacity (Chapelle 1935:285-288). In the opinion of Chapelle, "Some of these vessels were, without doubt, the highest development of the sailing-ship; combining speed, handiness, cargo-capacity and low operating costs to a degree never obtained in any earlier square-rigger" (Chapelle 1935:287). According to Howe and Matthews (1926), at least 121 medium-clippers were constructed prior to 1858. Construction characteristics preserved in the remains of the King Philip may provide additional insight regarding the evolution of hull design from a form emphasizing maximum speed to one emphasizing an optimum balance between speed and cargo capacity.

The sailing career of the King Philip may be fairly typical of contemporary merchant sailing vessels. The following brief summary of her 21 years at sea has been largely adapted from information contained in the files of the GGNRA. The King Philip was a hard-driven vessel with a reputation for making a good passage. Twice during her life, she was set on fire by her crew. The first time, while in the port of Honolulu in 1869, she was so badly damaged that she was condemned and later sold to the firm of Pope and Talbot. Following extensive repairs to her bow, using Douglas fir to replace the burned timbers (Delgado 1985a), she was back at sea carrying wheat from the Pacific Coast to England and, later, loads of guano from Howland's Island to Hamburg. On 18 May 1874, the King Philip was again set ablaze by her crew while lying at anchor in the Chesapeake Bay, enroute from Baltimore to San Francisco with a load of pitch and oakum. On this occasion, the crew mutinied, requiring the U.S. Navy to restore order to the ship. On this same voyage, which was to be her last long-distance haul, the King Philip was severely damaged during a gale off the South American coast. Following four months of repairs in Rio de Janeiro, she continued on to San Francisco, arriving nearly a year after her departure. In 1875, the King Philip's rigging was reduced to that of a bark for the coastal trade (Delgado 1985a).

The wreck of the King Philip was well documented by contemporary newspaper accounts of the event. The following version is adapted from articles which appeared in the San Francisco Daily Alta California from the 25th through the 28th of January, 1878. At 6 a.m. on Friday, 25 January 1878, the King Philip was towed, "in ballast trim" (i.e., without cargo), from her anchorage in San Francisco Bay by the tug Lookout. As was common, she was towed out through the Golden Gate on an ebbing tide to a point opposite the "nine-fathom buoy", just inside the bar. A light northeasterly breeze was blowing at the time that the Lookout let go of the King Philip; however, the wind died off soon after, leaving her without sail. To add to her predicament, there was a heavy swell breaking over the bar.

At 11:27 a.m., not long after King Philip was let go by the tug, the tide turned back toward shore. Within a few hours, she had drifted to a point about one and a half miles south of the Cliff House. As she was in danger of being swept onto the beach, both anchors were deployed off of the bow. Neither anchor held, however, and she continued to drift toward shore. At approximately 2:30 p.m., still dragging her anchors, the King Philip was carried onto the beach, stern first, by the breakers. A few moments after grounding, the anchor cables were separated, apparently at the order of the captain, and the King Philip swung around broadside to the surf.

During high tide, at around sunrise on the morning of January 27, the King Philip was reported to be moving uneasily, but by mid-day she had settled into the sand and was immovable. Although she may have been carried slightly farther onto the beach by the breakers during high tide, she remained oriented parallel to the surf line with a slight list offshore (to port).

On January 26, the King Philip was sold at auction to John Molloy, as salvage, for $1050. Prior to her wrecking, she had been valued at $25,000 but was uninsurable, due to her condition. Salvage of the ship's fittings, sails, and rigging was facilitated greatly by the fact that one could walk aboard the vessel at low tide. About a month following the wreck, Molloy, having removed everything of value which could be easily reached, dynamited her upper works, in order to gain better access to fittings below deck.

The remains of King Philip's hull were exposed above the sand for several years. In fact, she was still showing 24 years later, when the lumber schooner, Reporter, wrecked on the beach at the same location in 1902. The King Philip subsequently became buried by beach sands and was not rediscovered until the spring of 1983, when severe winter storms uncovered the remains of her hull (Figure 4).

Atlantic

The Atlantic was built in New Bedford, Massachusetts, in 1851, specifically for use as a whaling vessel. She was a three-masted, double-decked ship, with a square stern, a billethead, and no galleries (WPA 1940). Registered as a 366.5-ton bark, she measured 116 feet, 10 inches long; 26 feet, 3 inches abeam; and 13 feet, 1 inch deep in the hold. The Atlantic made eight extended whaling voyages out of New Bedford between 1851 and 1881 (Hegarty 1959; Starbuck 1964). During this time, she hunted whales both in the Atlantic and in the Pacific whaling grounds. In 1881, the Atlantic began sailing out of San Francisco. From this port, she made five short voyages to the North Pacific and Arctic whaling grounds (Hegarty 1959) before her sailing career came to an end at Ocean Beach on December 17, 1886. The events surrounding the wreck of the Atlantic were described in great detail in contemporary newspapers. The following account, unless

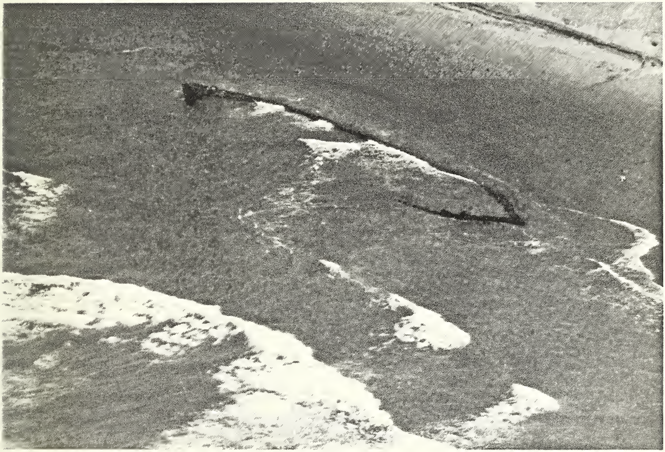


Figure 4. King Philip hull at maximum exposure during spring of 1983 (Photo courtesy of the National Park Service).

otherwise cited, is based on a story which appeared in the San Francisco Daily Examiner on 18 December 1886.

On the afternoon of 16 December 1886, having outfitted for another voyage to the Pacific grounds, the Atlantic sailed from San Francisco Bay on an ebb tide, under tow of the tug Sea Witch. Just before dark, the tug let loose of the Atlantic beyond the headlands and returned to port. There was considerable disagreement, later, regarding just how far out the Atlantic had been towed before being released; however, Captain Lockyer of the Sea Witch testified in the ensuing trial that he had towed the ship out about a mile to a mile and a half beyond the headlands, as far out as vessels were usually towed, unless they paid an extra $25 towage (San Francisco Daily Examiner; 24 December 1886).

Soon after the Atlantic was released, the sun set and a low fog rolled in over the water, leaving the stars shining above but completely hiding the shoreline. With the breeze blowing directly out of the west, it was necessary to tack first to the south, in order to make enough headway to avoid the Seal Rocks. To the misfortune of the Atlantic and her crew, the wind died after the third tack, leaving the vessel helplessly adrift in an unusually heavy surf. Captain Warren deployed first one anchor and then the other, but neither one held. Dragging both anchors, the Atlantic grounded, stern first, on Ocean Beach at approximately 4 a.m.

Upon contacting the beach, the breakers lifted her hull and slammed it with such force against the sand that she began to break apart almost immediately. Of the 43 men on board, only 11 survived, including Captain Warren. Several of the casualties were swept overboard by the breakers or were crushed by falling masts. Several others drowned in the forecastle where they had been sleeping. As a result of these deaths, the owners of the vessel, J. and William R. Wing were indicted, along with Captain Thomas Warren, for manslaughter, due to their apparent negligence (San Francisco Daily Examiner; 24 December 1886).

The scene at the beach following the wreck (Figure 5) was described in great detail by the San Francisco Daily Examiner (18 December 1886). The following excerpt from this article was written in a romantic style, however, it contains numerous details regarding the distribution of wreckage from the fractured vessel.

> The beach for a mile either way was strewn with all sorts of debris, from whole sections of deck planking, still belted to their heavy beams, down to splinters of a hand's breadth in size... The debris is almost impossible of description, so thoroughly was it broken and distorted... The condition of the wood was severely commented upon...it being so rotten... What there was to be seen of the remains that held together were lying on the port side, the bow well out in the foaming breakers,...the stern lay at about the extreme limit reached by the dying waves at medium tide...the bowsprit was broken away from the stem until the

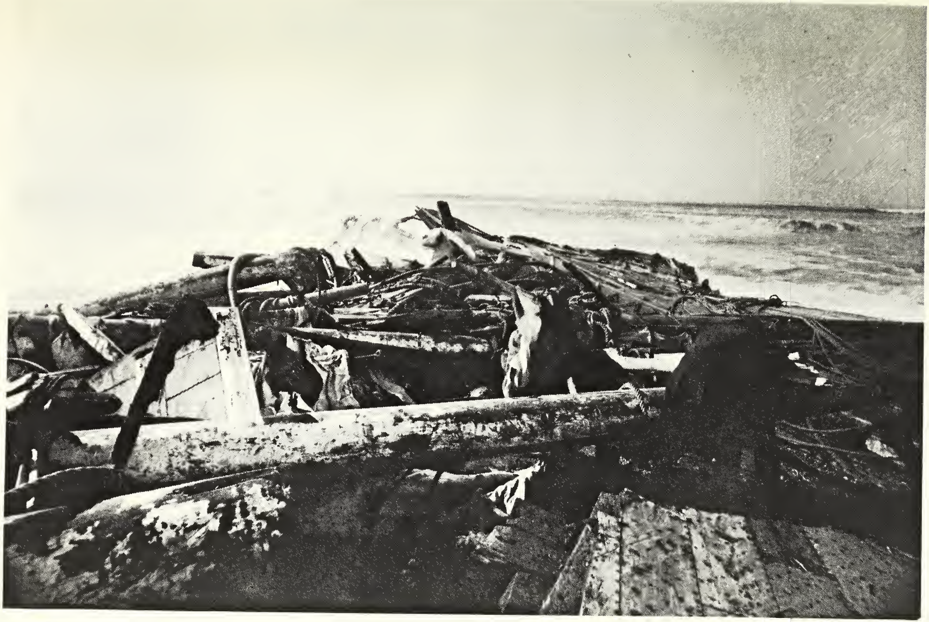


Figure 5. 1886 wreck of the New Bedford whaler, Atlantic. View toward the bow from amidships (Photo courtesy of the National Maritime Museum, San Francisco.)

> opening resembled the jaws of some long-snouted monster. From these booms dangled the chains and bobstays, writhing with the heavy waters like so many snakes. The whole of the starboard bow, from bulwarks to keel, was above water whenever the breakers receded, and though badly shattered the timbers clung together through the binding influence of copper sheathing, which held with wonderful tenacity... The heavy wire standing rigging and the strands and sheets and halliards were twisted into puzzling knots by the vagaries of the sea (San Francisco Daily Examiner, 18 December 1886).

Although mention is made in the above account of the rotten condition of the wood, Major Blakeney of the life-saving station commented, in the same article, upon the surprisingly good condition of her timbers. Major Blakeney:

> I have examined her timbers, and considering her age (thirty years) was surprised to find them in such a sound condition. Of course, some timbers were found decayed, but this might very well happen in a vessel of much more recent construction. Her main timbers were of live oak and her original fastenings of copper. There are, however, many bolts and spikes in her of galvanized and plain black iron. In many instances I found these latter fastenings corroded, rusted away and the timber surrounding them affected (San Francisco Daily Examiner, 18 December 1886).

Blakeney attributed the rapid speed of the vessel's disintegration to the poor condition of its many iron fasteners, in combination with the "wonderfully heavy surf in which she stranded" and the fact that the "vessel was kept from coming high up on the beach, as she otherwise undoubtedly would have done", due to her anchors being out.

Thousands of spectators flocked to the beach over the next two days to see the wreck and to collect whatever souvenirs they could carry away. Their enthusiasm for collecting was somewhat curtailed by the efforts of the salvage crew. Salvage rights to the Atlantic were purchased by Adolph Sutro, proprietor of Sutro's bath house, located within sight of the wreck at the north end of Ocean Beach. The San Francisco Daily Examiner of December 19 reported that Mr. Sutro's crew had removed several tons of wood from the wreck, which was easily reached at low tide. This material was piled on the beach above the high-water mark where it was presumably stripped of fittings and sheathing and both hauled away.

Reporter

The Reporter was a three-masted schooner, built in Port Ludlow, Washington in 1876. She was constructed of Douglas fir with iron fastenings and was not sheathed. Her physical dimensions were slightly larger than those of the Atlantic, the Reporter measuring 141.4 feet long, 34 feet abeam, and 10.6 feet deep; however, her gross tonage, registered as 350 tons (U.S. Government Printing Office 1900), was less than that of the Atlantic. The Reporter operated as a lumber schooner along the Northwest Coast for 26 years before coming ashore at Ocean Beach early on the morning of 13 March 1902.

At the time of her wreck, the Reporter was based out of San Francisco. Six days prior to her demise, she had sailed for San Francisco from Grays Harbor, Washington, with a load of pine lumber (400,000 board feet, in all). Early on the morning of March 13, Captain Adolph Hansen headed his vessel directly toward Ocean Beach, reportedly mistaking a light onshore for the Point Bonita light, located on the north headland of the Golden Gate. By the time he had realized his mistake and tried to bring the schooner hard about, the Reporter was caught by the strong current of the breakers. At approximately 4 a.m., she grounded "directly off the point where the King Philip was wrecked" (San Francisco Call, 14 March 1902):

"The schooner was rapidly lifted inshore by the breakers until she lay starboard side on [bow to the north], less than a hundred yards from the low water mark. During the day she heaved and lurched about until she was lying almost stern on" (San Francisco Call, 14 March 1902). Historic photographs of the beached schooner (e.g., Figure 6) show her high up on the beach in the latter position. Shortly after beaching, the Reporter began to break apart in the surf. An article in the San Francisco Call from the following day reported that her back had broken and that "a piece of the keel and sections of her rail came ashore before noon [on the 13th]. She will certainly go to pieces within a day or two" (San Francisco Call, 14 March 1902). An historic photograph of the wrecked vessel, a copy of which is on file at the GGNRA, shows the cabin section of her stern lying on the beach, separate from the remainder of the vessel.

Aberdeen

The steam schooner, Aberdeen, was constructed by J. Lindstrom in 1899 for the Pacific lumber trade. Her hull was laid in Aberdeen, Washington. The dimensions of the 499-ton vessel were 169.8 feet long, 34.2 feet across the beam and 11.8 feet deep in the hold (U.S. Government Printing Office 1906). Powered by a 425-horsepower compound steam engine, she was capable of hauling 500,000 board feet of lumber (Lyman 1943). Very few other details of her construction are known; however, it is presumed that she was not sheathed, as she was built specifically for use in the cold waters of the Northwest Coast.

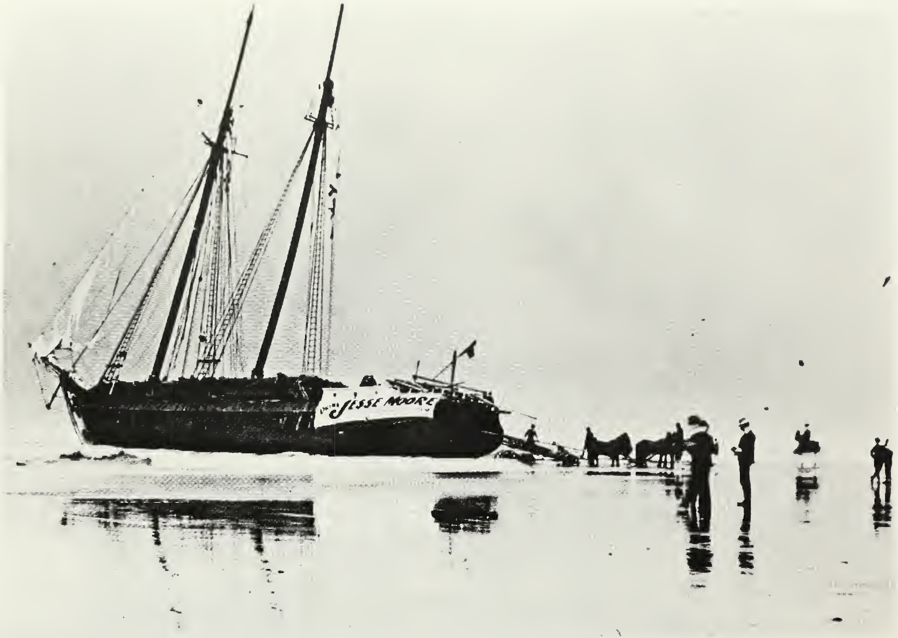


Figure 6. Wreck of the lumber schooner, Reporter, 1902. (Photo courtesy of the National Maritime Museum, San Francisco.)

The Aberdeen was operated by the Pacific Lumber Transportation Company of San Francisco for several years. In 1911, she was sold to Fred Lindeman who used her for hauling garbage from Oakland to a point off the Farallon Islands (McNairn and MacMullen 1949). It was on a return trip from one such haul that the Aberdeen capsized in heavy seas off the San Francisco Bar on 23 January 1916 (Lyman 1943; San Francisco Chronicle, 24-30 January 1916). Her wreckage washed ashore along a three-mile stretch of Ocean Beach over a period of days (Figure 7). Despite the broad scatter of the wreckage, the area shown in Figure 7 indicates that several large sections of hull washed ashore relatively close to one another. It is not known whether any of her machinery came ashore.

Previous Archaeological Investigations

During the spring of 1982, the remains of the King Philip's wooden hull were exposed by a winter of severe erosion. Initially, the vessel was reported to archaeologists of the GGNRA by a resident of the area. Attempts to conduct further investigations at the time were not fruitful, as three inches of a few frames and the tip of the stem were the only portions visible (Delgado 1985b). In March of the next year, following another winter of severe storms, a much more extensive exposure of the vessel occurred. Measurements of the hull dimensions (Figure 8) provided supporting evidence for the historical references which had indicated that the remains may be those of the King Philip. A thorough analysis of construction materials from the exposed hull has built a sound case for its identity as the King Philip (Delgado 1985b).

Documentation of the King Philip's remains continued during the spring of 1984, when waves washing over the hull scoured deep holes at the bow and stern, allowing diver access to a depth of nine feet at the stern. Construction techniques and materials have been carefully noted, drawn and photographed during periods of vessel exposure. Of particular interest to the Ocean Beach magnetometer survey is the documentation of large ferrous elements at various locations on the hull, including the occurrence of three "massive breasthooks" at the bow and of three "crutches", similar to the breasthooks, at the stern (Delgado 1985b). Of special note was the occurrence of Reporter wreckage intermixed with that of the King Philip:

> A tangle of wire rope rigging from Reporter lies in and over King Philip's bow [Figure 9]. In 1984, beach erosion exposed wire rope and shrouds landward of King Philip's bow. Douglas fir timber, fastened with iron drift bolts, was also observed and documented. A lead soil pipe was found wedged in King Philip's stern; it may be from either vessel. An iron turnbuckle, a late 19th century rigging fitting, and presumably from Reporter, lies inside King Philip 26 feet aft of the bow. The most diagnostic artifacts were double bobstays, presumed to have come from Reporter, inasmuch as they are too small for a vessel of King Philip's size, and King Philip's bobstays would have probably

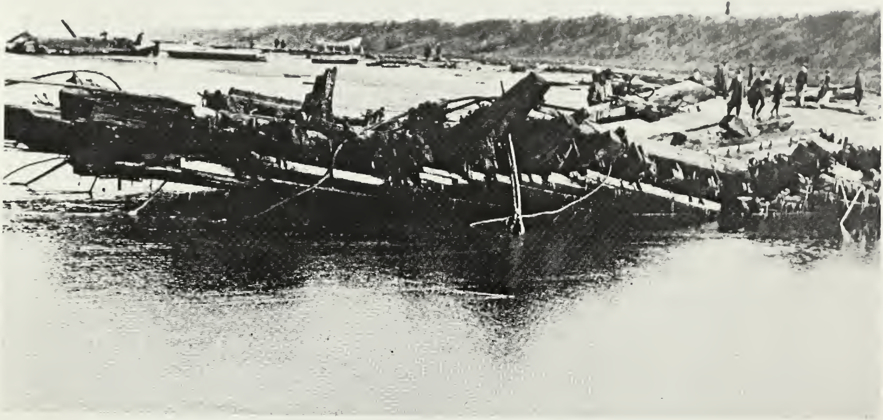


Figure 7. Wreckage of the steam schooner, Aberdeen, washed ashore on Ocean Beach, 1916. (Photo courtesy of the National Maritime Museum, San Francisco.)

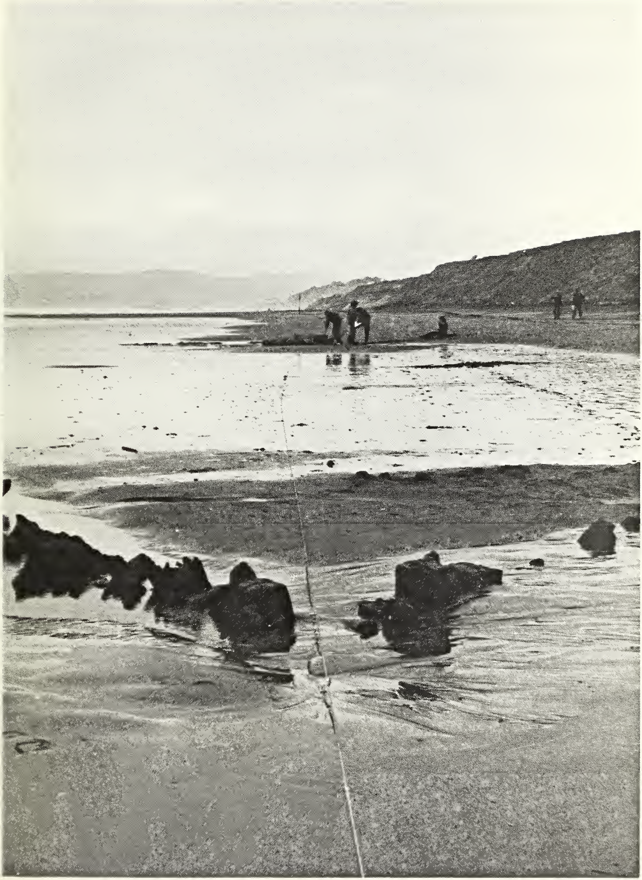


Figure 8. Remains of King Philip during recent exposure. View from stern to bow, facing north. (Photo courtesy of National Park Service.)

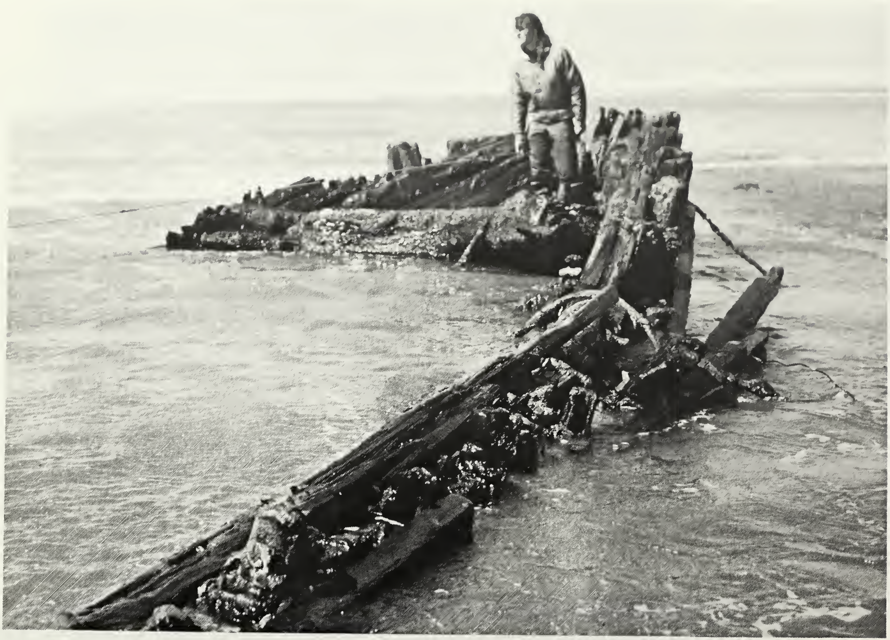


Figure 9. Exposed bow of King Philip. Note the wire rigging of Reporter draped across the hull. (Photo courtesy of National Park Service).

> been salvaged. Photographs of the [Reporter] wreck show the same style of bobstay...[and that] her bobstay had been torn away with points of separation matching those on the bobstays on the beach (Delgado 1985b).

Extensive documentation efforts during the spring of 1983 included hydraulic probing of the hull's interior and a preliminary magnetometer survey of the vessel. Probing revealed a maximum depth of 10 feet to the hull interior. Material believed to be ballast was also encountered at a depth of 7.8 feet below beach level in three locations (Delgado 1985b). It is estimated that approximately 45 percent of the hull remains intact. The results of a magnetometer survey, involving three traverses across the wreck site with a Geometrics Unimag Model G-846 magnetometer, were reported by Kelly (1983). The largest magnetic anomaly recorded at this time was an 863-gamma peak over the exposed bow of the King Philip. Another large anomaly of 700-gamma intensity was recorded amidships. The magnitude of these anomalies was significantly less during the current study, due to the presence of from 8 to 11 feet of sand over the hull.

Aside from the documentation of the King Philip and Reporter wreck sites by NPS, only one other archaeological investigation has been conducted on Ocean Beach, prior to the current study. In 1983 NPS staff performed a magnetometer survey of a portion of Ocean Beach and an adjacent offshore area in the vicinity of Fort Funston (Delgado, et al. 1984). Fort Funston is located at the southern end of Ocean Beach. The objective of this survey was to located the wreckage of the U.S. revenue cutter C. W. Lawrence which reportedly wrecked in the area on 25 November 1851. The magnetometer survey included an offshore area measuring 700 x 700 yards. Several transects were also surveyed on the beach, adjacent this area. Only one magnetic anomaly was identified as a result of this survey. This was a 300 gamma anomaly located in the offshore area. Neither the source of this anomaly nor the location of the C. W. Lawrence were verified.

CHAPTER IV
RESEARCH DESIGN

Magnetometer Survey Methods

The Ocean Beach magnetometer survey was performed by a crew of three EH&A archaeologists, during late September and early October, 1987. Autumn was chosen as the optimum time for conducting the survey, as the beach is at its maximum width, and weather conditions are most favorable at this time of year.

Instrumentation used for the survey included an EG&G Geometrics Model G-856 proton precession magnetometer as a field instrument, an EG&G Geometrics Model G-866 magnetometer as a base station, and a Toshiba T1100+ lap-top personal computer for data storage and processing. The G-856 magnetometer is powered by eight D-cell batteries and mounts in a shoulder harness for operation by a single individual (Figure 10). The G-856 sensor is designed to be carried in a pouch at the back of the operator's harness or at the end of an aluminum staff. During the survey, the G-856 sensor was mounted on a staff at a height of 6 feet. The G-866 base station magnetometer (Figure 11) was powered by two 12-volt, wet-cell batteries. The G-866 sensor was mounted on a wooden stand at a height of 4 feet.

Base station readings were recorded by the G-866 magnetometer at 5-second intervals throughout the course of each day. By interfacing the G-866 with the Toshiba portable computer, base station readings could be automatically stored on floppy disk as an ASCII data file. The computer was operated from the same power source as the G-866. Likewise, readings stored in the internal memory of the G-856 survey magnetometer during the course of the day were transferred to computer disk each evening, at which time initial data processing and plotting was performed to insure the quality of the data.

The survey was conducted on a controlled survey grid with measurements of the magnetic field recorded at uniformly spaced intervals along parallel transects. Transects were oriented approximately perpendicular to the line of the surf. Grid spacing (i.e., the distance between adjacent magnetometer readings) was 6 feet in the vicinity of the King Philip and Reporter wreck sites, and 12 feet for the remainder of the survey area, including two small sections of riprap-covered slope which were surveyed (Figure 3b; eastern margin of survey area). The area suspected to contain wreckage from the Atlantic was later resurveyed at a 6-foot interval, providing resolution equal to that obtained for King Philip and Reporter.

Horizontal controls for the survey grid were tied to the City of San Francisco's project datum line, referred to as the "C"-line, by surveyors from the City's Survey Division. A temporary wooden hub, set into the beach at the foot of Ortega Street by the city's surveyors, was designated as a working datum for the survey. This point, located 6,765.61

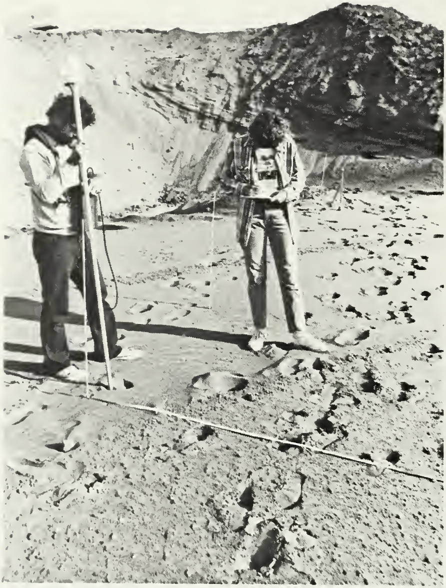


Figure 10. Crew member operating G-856 Magnetometer.

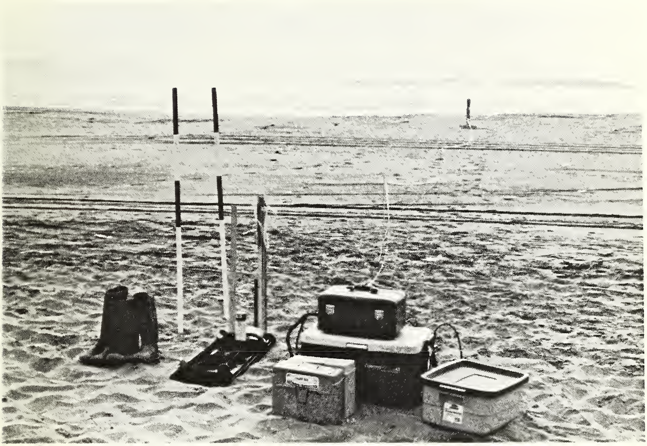


Figure 11. G-866 magnetometer interfaced with portable computer at base station; sensor in background.

feet north along the "C"-line and 202.43 feet west of the "C"-line, was given the designation of North 900/West 100 (N 900/W 100) on an arbitrary grid system. As a convenience, each whole-number increment along the survey grid lines was assigned a value of 6 feet, thus the distance between N 900 and N 800 is 100 grid units or 600 feet. Use of this whole-number system for designating grid coordinates not only simplified record keeping, but also greatly reduced the chance for error in conducting the survey. Appendix A (unattached) contains a complete list of city coordinate system equivalencies (based upon the "C"-line) for each of the survey grid coordinate pairs. Using these equivalencies, any data point within the survey area can be accurately relocated on the beach by surveying from a permanent city datum.

Two parallel baselines, one located at W 100 and the other at W 120, were established on the beach using a Wild T-2 theodolite. All distance measurements were taped using Keeson fiberglass survey tapes. These baselines, oriented approximately parallel to the "C"-line, were marked on the beach using 3-foot wooden laths, hammered into the sand to their full length, at 120-foot (20-unit) intervals. Survey transects were established by stretching measuring tapes perpendicular to the baselines (approximately east/west), from the base of the riprap, out into the surf. Points of intersection between survey transects and the baselines were demarcated by placing 3-foot wooden dowels along the baselines at 6- or 12-foot intervals between the laths. The dowels served a dual purpose: first, as points of reference for positioning the transect tapes and secondly, as anchor points for the measuring tapes so that they could be positioned along the survey transects by a single person. When surveying the surf zone and the area between the W 100 baseline and the riprap, baseline dowels were also used as sighting points for positioning the western end of the tapes. Horizontal control and record-keeping were greatly facilitated by marking the survey tapes at 6-foot intervals with red and blue spray paint, alternately.

During the course of a typical day's survey, the G-856 magnetometer was operated by one crew member on a nearly continual basis. Magnetic field intensity was recorded at 6- or 12-foot intervals along each transect (depending upon the section of the beach being surveyed) using the G-856. The other two crew members shared the constant responsibilities of recording the beginning and ending coordinates of each transect, holding the tape out of the surf at the western end of each transect (Figure 12), repositioning the tapes for each subsequent transect, and monitoring the base station.

Operation of the base station generally involved little attention during the course of the day, once it was set up and running at the start of each morning. The location of the base station was varied throughout the course of the survey for security reasons, as the project area was nearly 3,000 feet long and had a substantial amount of pedestrian traffic. Locations for setting up the base station were, therefore, chosen reasonably close to where we planned to be surveying on any given day. The

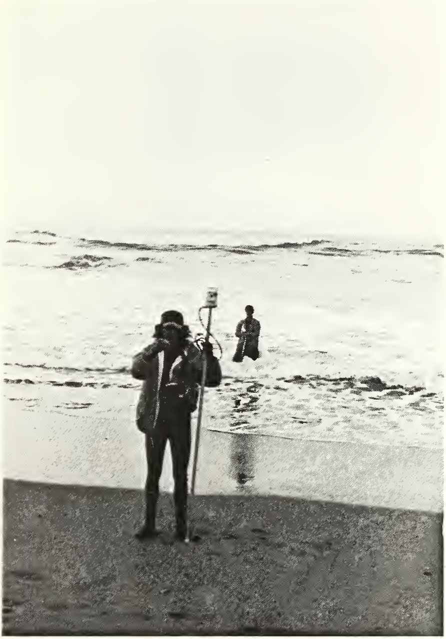


Figure 12. Surveying the surf line. Visual alignment of tape along transect allowed extension of survey area well into surf zone.

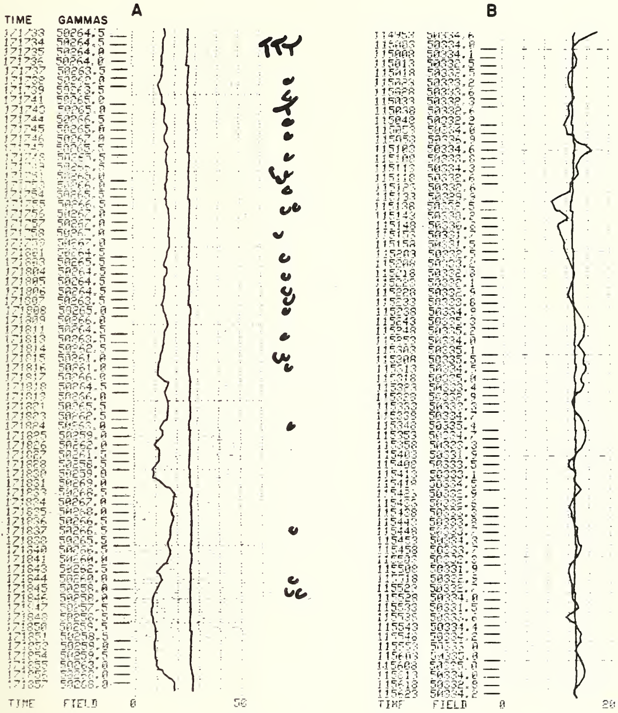
base station sensor, as mentioned above, was mounted 4 feet above the sand on a wooden stand. The sensor was positioned as close to the high tide line as possible, without running the risk of being knocked over by a large wave.

Prior to initiating the survey, an experiment was conducted to determine what effects, if any, passing motor vehicles might have on the background magnetic field of the beach. By varying the distance of the base station sensor from the highway and marking the pass of each car and truck on the G-866's paper strip chart (Figure 13), it was determined that traffic had no noticeable effect on the local magnetic field at distances greater than 130 feet from the highway. This is in agreement with Breiner's (1973:46) calculation that a 1-ton automobile at a distance of 100 feet should only produce a 1-gamma deviation in the magnetic field. To be conservative, the base station sensor was positioned at a distance of at least 130 feet from the highway throughout the course of the survey. Test strip charts were also run daily on the G-866 (Figure 13), in order to determine whether the level of solar-induced magnetic activity was acceptable to allow the collection of meaningful survey data.

Upon completion of the survey at the original 6- and 12-foot intervals, a mosaic magnetic contour plot, in variable density dot-matrix format, was pieced together for the entire project area. A preliminary analysis of the resulting map revealed several interesting anomaly patterns believed to be potentially caused by the presence of buried wreckage. As mentioned above, selected portions of the 12-foot survey area encompassing these patterns (figures 3b and 3c; areas C and D, respectively), were resurveyed at a 6-foot sample interval, in order to increase the resolution of the data to that achieved by the survey of the King Philip and Reporter wreck sites.

Data Processing and Contour Mapping

Initial processing of magnetic data was performed on a daily basis. The MAGPAC computer software package, developed by the staff of EG&G Geometrics (Sunnyvale, California), was used for all data transfer and processing conducted while in the field. Upon completion of each day's survey, the corresponding data was transferred, in ASCII format, from the internal memory of the G-856 to the 3.5-inch computer floppy disk holding that particular day's base station data. Due to the large number of files generated during the course of processing the data, it was found convenient and often necessary to store each day's data files on a separate floppy disk. The first step performed in preparation for displaying the data was to remove the diurnal variation from the survey data using the "Diurnal" mode of the MAGPAC software package. Once this was accomplished, survey grid coordinates were inserted into the corrected data file, relying upon the daily field notes for this information. Finally, the sequence of the data from alternate transects was reversed, as adjacent transects were



A Test of traffic noise effect on background magnetic field; sensor located approximately 130 feet from highway
c = car t = truck

(10 gamma division between lines)

B Typical Base Station Strip Chart showing normal variation in background magnetic field

(4 gamma division between lines

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Figure 13
G-866 Base
Station Test Charts

surveyed in opposite directions. At this point, the diurnally corrected and properly ordered data file was ready to be displayed either as magnetic profiles of individual transects (Figure 14) or as a variable density dot-matrix contour map (Figure 15). Both forms of data display were used as interpretive aids during the course of field work.

Upon returning to the offices of EH&A in Austin, Texas, all diurnally corrected data files were combined and transferred as a single ASCII file to EH&A's Digital Equipment Corporation VAX, mainframe computer system. Using an Intergraph computer-assisted-drafting work station and a Digital Terrain Modeling (DTM) engineering software package, magnetic line-contour maps were generated from the combined data files for the entire survey area (Figure 3). The DTM contouring program selected for use in this study utilizes a triangle interpolation routine which honors the value of each data point, sacrificing some degree of contour smoothness for accuracy. In other words, contour lines are never drawn on the wrong side of a data point, as is allowed by some grid interpolation routines. A comparison of a sample computer-generated contour map, produced by this method, with a manually-interpolated contour map of the same data set, hand-drawn by the principal investigator, indicates that the triangle interpolation routine is extremely well suited to this application, producing a map which is a precise and accurate reflection of the data.

Initial contouring of the data revealed a degree of inconsistency between adjoining data files which had been created on different survey days. This was especially noticeable when the location of the base station had changed from one day to the next. The result was that the magnetic data recorded on any given day contoured normally, while a sharp bend in the contour lines often occurred at the break between one day's survey and the next. This problem was solved by adding a unique correction factor to the magnetic readings within each day's data files, effectively adjusting the value of the background magnetic field component, so that the total magnetic field intensity of all data points was comparable. Correction factors were determined manually by interpolating between adjacent transects which had been surveyed on different days. The corrected values are provided in Appendix A, as these correlate with the contoured data.

Interpretive Methods

The interpretation of magnetic data from Ocean Beach was conducted with three objectives in mind. First, an attempt was made to identify all magnetic anomalies resulting from visible sources within the project area, so that these data could either be ruled out of consideration for potential significance or be taken into account for the masking effect which they may have upon other anomalies. Second, based upon a predictive model which describes magnetic anomaly patterns expected to result from various types of wreck sites, areas of potential historic significance were delineated. Third, where possible, the depth of anomaly sources was estimated, in order to determine whether they are buried too deeply in the

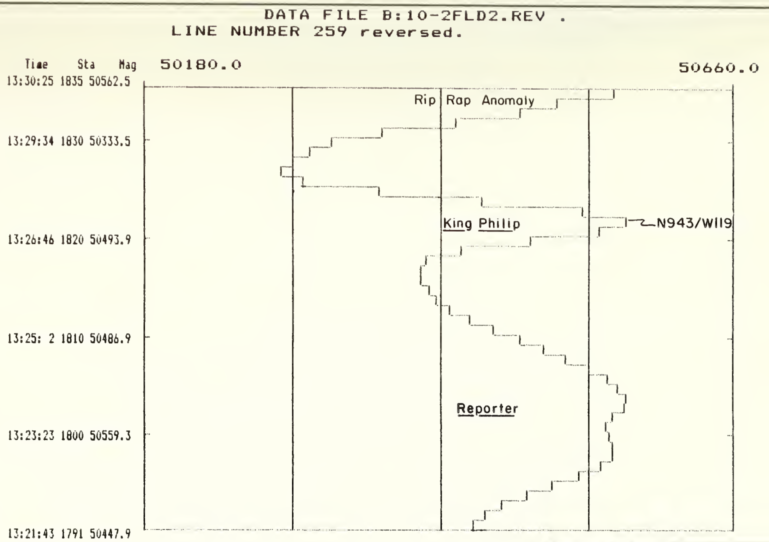

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Figure 14
Magnetic Profile of
Transect Across King Philip
Bow Anomaly

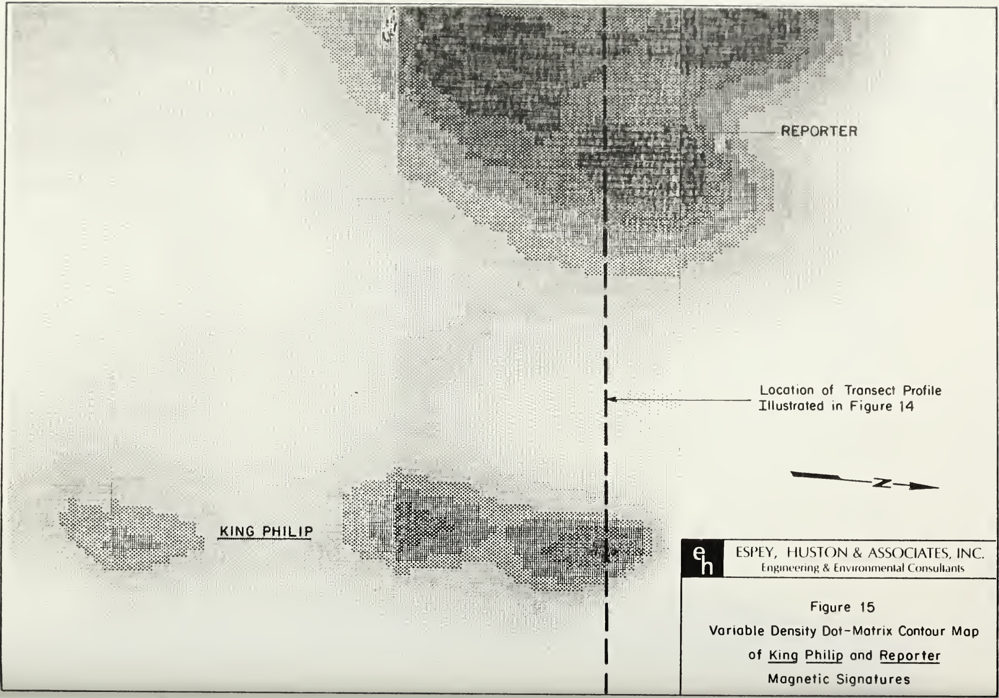

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Figure 15
Variable Density Dot-Matrix Contour Map
of King Philip and Reporter
Magnetic Signatures

sand to be affected by construction of the seawall or are too shallow to be considered potentially significant. A description of the methods employed to accomplish each of these objectives is provided below, including a summary of the predictive model developed specifically for this project.

Visible Anomaly Sources

Due to the high incidence in the project area of modern surface materials capable of producing magnetic anomalies, a large amount of data contamination was expected to occur. Unless accounted for, extraneous anomaly sources could greatly confuse the interpretation of data. This was especially true along the riprap-covered slope at the top of the beach. The location and nature of all visible anomaly sources within the project area were, therefore, recorded during the course of the survey. When possible, these sources were physically removed prior to surveying an area. Visible anomaly sources were, by far, most often associated with the riprap occurring on the slope between the Great Highway and the beach. Anomaly sources located on the slope generally consisted of concrete rubble (small amounts of which contained steel reenforcement bar), discarded granite building stones, and igneous boulders. As it was not possible to remove these materials prior to conducting the survey, careful note was made of the relative abundance of each type of material along the entire length of the slope through the project area. In addition, the face of the slope was photo-documented in 120-foot sections to allow a visual correlation of magnetic anomalies with the material occurring as riprap on corresponding sections of the slope. Other features, noted during the course of the survey and mapped as possible anomaly sources, include: all timbers lying on or protruding from the sand (note was made in each such case as to whether iron fastenings were present); the remains of intact beach hearths; and major topographic features, such as winter high-tide berms and beach cusps. Upon completion of a line-contour map, the locations of visible anomaly sources were plotted on a working copy and visually correlated with magnetic anomalies. A majority of the high gradient anomalies, located near the slope base, were accounted for in this manner.

Anomaly Pattern Recognition

Very few detailed studies, such as this one, have been conducted in which magnetic contour maps have been produced of known shipwreck sites, using tightly controlled and closely spaced survey points. Such studies would be helpful in the interpretation of the Ocean Beach magnetometer data. Fortunately, two known examples of historic shipwrecks, the King Philip and the Reporter, are present within the survey area. Information regarding these vessels has been invaluable to the interpretation of anomaly patterns occurring elsewhere on the beach. For example, in the case of the King Philip, the composition, orientation, depth of burial, and general state of preservation of her hull are known. Less information is available for the Reporter; however, from historical documentation, we know the composition of her hull, the vessel's location and orientation prior to disintegrating in the surf, and a few of the details regarding the manner in which she broke apart. The magnetic anomaly patterns of these two wreck sites have been utilized extensively in the interpretation of data from the remainder of the survey area.

In addition to the use of the King Philip and Reporter wreck sites as comparative examples, the interpretation of data from Ocean Beach has relied heavily upon a number of expectations, or working hypotheses, regarding the nature of anomaly patterning for wreck sites occurring in a beach environment. Delgado and Murphy (1984), in their classification scheme for environmentally exposed shipwreck sites (i.e., wrecks occurring and remaining exposed in dynamic environments, such as beach or nearshore settings), recognized three distinctive site patterns which they referred to as buoyant hull sites, buoyant hull fracture sites, and buoyant structure sites. Buoyant hull sites are those, such as the King Philip, in which a ship comes ashore and settles into the sand, relatively intact. Buoyant hull fracture sites occur when the hull of a ship comes ashore intact, but breaks apart on the beach and is dispersed by the surf. The wrecks of the Atlantic and the Reporter fall into this category. Buoyant structure sites form when a ship breaks apart offshore and washes onto the beach in pieces, as did the Aberdeen. Delgado and Murphy's terminology is followed throughout this report.

The following sections comprise a preliminary predictive model of anomaly patterns expected from each of Delgado and Murphy's (1984) three types of environmentally exposed shipwreck sites: buoyant hull, buoyant hull fracture, and buoyant structure wreck sites. Magnetic anomaly patterns, observed within the survey area, which resemble either the pattern of the King Philip or Reporter wreck sites (Figure 3a), or one of the following hypothesized patterns for environmentally exposed wreck sites, were interpreted as having a potential for historic significance.

Buoyant Hull

The anomaly pattern of buoyant hull wrecks, such as the King Philip, may differ from one wreck to the next, due to differences in the materials used for construction. Certainly there would be some dramatic differences between that of a steel-hulled versus a wooden-hulled vessel. Two important characteristics might be expected, however, for the majority of buoyant hull anomaly patterns. First, we would expect a linear distribution of multiple anomaly peaks within the overall pattern produced by the remains of an intact hull. In the case of a wooden-hulled vessel, the anomaly pattern may appear as a complex, elongated anomaly, containing areas of high and low magnetic intensity within its boundaries. The long axis of the anomaly pattern should be oriented along the same heading as the long axis of the hull. A classic example of this type of signature is that of the wooden-hulled steamboat Bertrand, illustrated by Petsch (1974:Figure 18). Arnold (1987:35), similarly, observed the occurrence of multiple peaks in the anomaly pattern of a concrete-hulled vessel. As it turns out, the anomaly pattern of the King Philip (figures 3a and 15) also exhibits an extremely definitive linear pattern.

Second, the long axis of the anomaly pattern may often be oriented parallel to the surfline, due to the tendency of a drifting hull to turn broadside to the waves (e.g., Figure 16). This, of course, depends upon whether the anchor lines are released when a vessel makes contact with the beach, as was done in the case of the King Philip. Failure to release the anchor lines may keep a vessel at a right angle to the surf and, by holding the hull in the most violent portion of the surf zone, increase the chances of it breaking apart. Similar circumstances apparently contributed to the rapid disintegration of the Atlantic (San Francisco Daily Examiner, 18 December 1886).

Buoyant Hull Fracture

When a ship's hull breaks apart soon after becoming beached, the potential for anomaly sources, such as iron fittings or magnetic ballast material, to become scattered away from the main body of the wreck is much greater than for a buoyant hull. Waves of sufficient energy to break up a ship might also be expected to distribute vessel elements high onto the beach. At the same time, littoral drift would tend to transport buoyant elements downcurrent. We would, therefore, expect a buoyant hull fracture to consist of a pattern of multiple anomalies (i.e., wreck scatter) radiating upslope and downcurrent from an area of more tightly clustered, higher-intensity anomalies (i.e., the area of hull break-up). Smith et al. (1987), for example, observed a landward scatter of wreckage from the fractured remains of a Civil War period anti-torpedo raft on Mustang Island in Texas.

Buoyant hull fractures should be distinguishable from buoyant hulls, due to horizontal diffusion of the complex, linear anomaly pattern often produced by intact hulls, together with a pattern of lower intensity anomalies radiating inland and downcurrent from this source. Two buoyant hull fractures are known or suspected to exist within the project area. Portions of the Reporter wreckage have been previously located, intermingled with the wreckage of the King Philip, while the Atlantic reportedly washed ashore 1,000 feet south of the King Philip, subsequently scattering debris over a mile of beach.

Buoyant Structure

Ships, such as the Aberdeen, which break apart offshore and then wash onto the beach, may leave a trail of wreckage scattered along miles of shoreline. While larger iron components (e.g., the steam engine of the Aberdeen) may tend to remain offshore, this would depend upon whether such elements remained attached to large, buoyant sections of the vessel. The possibility of magnetically distinguishing a wreck of this nature from other sources of flotsam would depend upon the size and number of vessel elements which washed ashore and upon the area of their dispersal over the

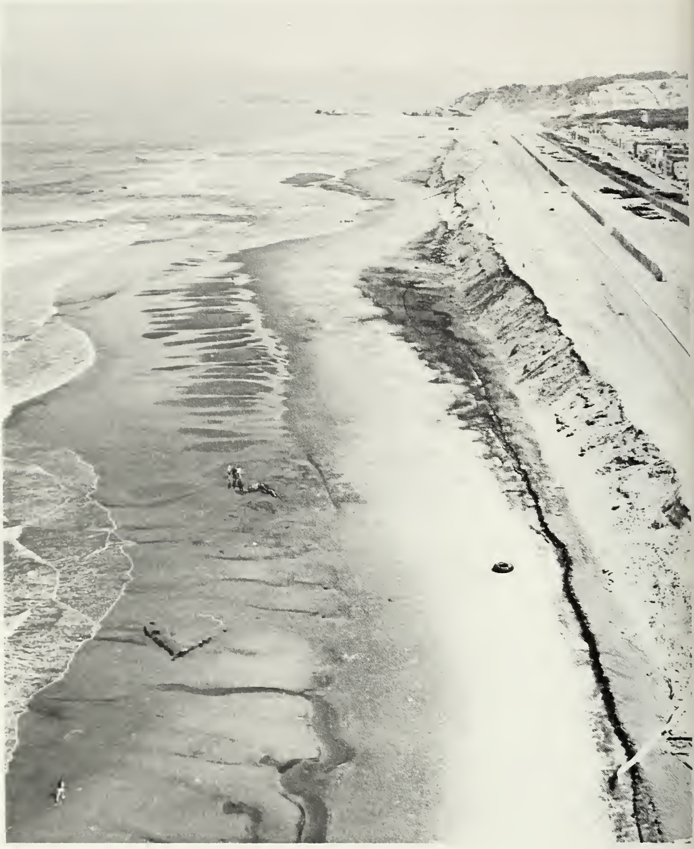


Figure 16. King Philip/Reporter wreck site at low tide during 1983 exposure. (Photo courtesy of National Park Service.)

beach. Unlike the anomaly pattern of a vessel which breaks up after coming ashore, the pattern of a buoyant structure wreck is expected to consist of non-clustered anomalies, of varying intensities, scattered unevenly across the beach.

Photographs taken of the Aberdeen wreck site in 1916 (figures 7 and 17), illustrate a feature of buoyant structure wreck sites, which may also be common to buoyant fracture sites, that is, the distribution of smaller wreckage, or flotsam, along a strandline. It is expected that heavier pieces of wreckage, and presumably larger anomalies, would tend to be located closer to the surfline, while lower-intensity anomalies may be concentrated higher on the beach, in association with the high-water mark (strandline). Provided that this material was not completely scavenged for lumber and firewood before it could become buried, strandline wreckage from either form of wreck site may result in a linear pattern of relatively weak anomalies, oriented parallel to the surfline. This, of course, would depend upon the amount of ferrous material associated with the flotsam.

In comparison with buoyant fracture sites, it is also conceivable that higher intensity anomalies would tend to be located farther out into the surf zone on buoyant structure sites. The reasoning behind this statement is that elements of a buoyant fracture wreck come ashore while still part of an intact buoyant hull. For as long as the hull remains intact, high tides may continue to carry the vessel farther inland. The fractured remains of a buoyant structure wreck, on the other hand, may be less buoyant to begin with than an intact hull, and perhaps more susceptible to becoming embedded in the sand, due to the presence of broken and protruding elements.

Estimation of Anomaly Source Depth

Two methods available for estimating depth of anomaly sources were utilized during the course of the data interpretation. These include the vertical gradient method (Breiner 1973:52-53) and a "slope" technique (Breiner 1973:31). Estimation of depth to an anomaly source using the vertical gradient method requires that two magnetometer readings be taken at varying sensor heights over the point of an anomaly's highest intensity. Sensor heights used to perform this exercise during the current study were six feet and two feet. By subtracting the two readings obtained in this manner, then dividing this difference (dT) by the difference in sensor height (dz), the latter being four feet in this case, the vertical gradient (dT/dz), or fall-off rate, of an anomaly can be determined. An approximate maximum depth estimate can then be obtained by the formula for depth of a dipolar anomaly source, $z=3T/(dT/dz)$, where z is the estimated vertical distance from the sensor, T is the intensity of the residual anomaly (i.e., an anomaly's intensity relative to the local background field intensity), and 3 is the fall-off factor for a dipolar anomaly. Monopolar anomalies have a fall-off factor of 2 which results in a shallower estimate of depth using this method. By subtracting the height of the magnetometer sensor, used in the determination of T (in this case, 6 feet), from the value obtained for z, the approximate maximum depth to an anomaly source, below the surface of the beach, is estimated.

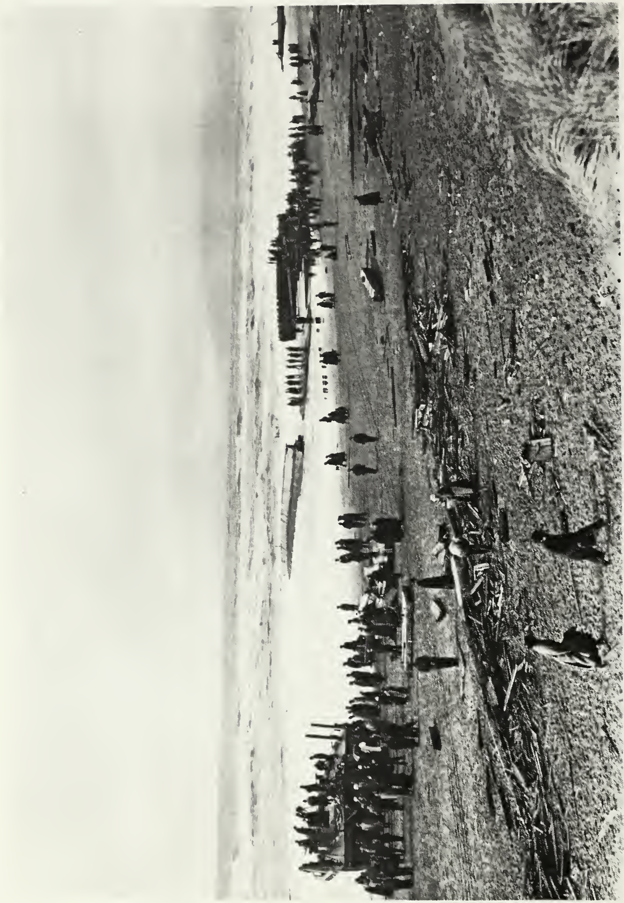


Figure 17. Beach scene following the 1916 wreck of the steam schooner Aberdeen. (Photo courtesy of the National Maritime Museum, San Francisco.)

Slope techniques for estimating source depth involve measuring the horizontal extent of an anomaly's gradient (i.e., slope) between points of inflection along the slope of the anomaly (Breiner 1973:31). Measurement of the horizontal distance between slope inflection points (see Breiner 1973:31; illustration) can be accomplished in two ways. The first involves drawing a profile of the anomaly along its axis (i.e., the line between its points of highest and lowest magnetic intensity). This is the equivalent of cross-sectioning a three-dimensional plot of the anomaly along the axis of its poles and only serves to emphasize the location of inflection points. The second method simply involves determining the points of inflection, along the polar axis of an anomaly, from inspection of the contour map, then measuring the distance between these two points with a ruler. The latter method sacrifices little in accuracy over the more time-consuming method of drawing an anomaly profile, since the horizontal scale of any profile is the same as that of the contour map from which the profile was projected. Once obtained, the horizontal distance between inflection points is multiplied by an empirically determined factor ranging from 0.5 to 1.5 in order to estimate the depth of the source. A value of 1.5 was selected for use here, based upon a comparison of the King Philip's actual depth with estimates which were calculated using both the vertical gradient and slope techniques.

CHAPTER V
EVALUATION OF ANOMALY PATTERNS

The results of a magnetic survey can be illustrated in a number of formats, including: line-graph profiles of the magnetic field along each transect; variable density, dot-matrix contour maps; line contour maps; and three-dimensional plots. Each has its advantages and disadvantages; therefore, it is recommended that analysis never rely solely on one method. The data from Ocean Beach has been displayed, throughout the course of the analysis, in all of the above formats; however, due to the large size of the data set, it was not considered desirable to reproduce every version here.

The format chosen for the display of magnetic data in this report instead combines features from all of the above methods in an attempt to make the presentation as readable, succinct and precise as possible. The result is a computer-generated line-contour map of the survey area which has been manually enhanced to highlight noteworthy features (Figure 3). In order to make areas of higher-than-normal magnetic intensity stand out, two degrees of shading were used to produce an effect, similar to that of a variable density, dot-matrix contour map, in which higher-intensity areas are shaded more darkly. The upper and lower limits of areas to receive shading were determined on the basis of a dot-matrix contour map of the survey area which was plotted at a 20-gamma contour interval and with a lower limit of 50,220 gammas (e.g., Figure 15). Areas on Figure 3 having a total field intensity in the range of 50,320 gammas to 50,400 gammas are lightly shaded. Areas having a total field intensity greater than 50,400 gammas are more darkly shaded. Local magnetic highs and lows (i.e., anomaly peaks) are indicated by positive (+) and negative (-) signs, respectively. The sign of an anomaly (+ or -) was not always readily apparent from inspection of the line contours; therefore, it was necessary to consult profiles of the magnetic field intensity for each survey transect (e.g., Figure 14) to verify the sign of the anomaly. The resulting composite presentation of the data, while not truly three-dimensional, contains all of the information to be found in a three-dimensional plot, with the added advantage of allowing fairly precise physical measurements of the data.

Figure 3 has been divided into six areas of interest, designated along the top margin as Area A through Area F. A verbal summary of the anomaly patterning observed within each of these areas is provided below in the section on non-visible anomaly sources. Anomalies or anomaly clusters of interest are indicated on Figure 3 by arabic numerals. These numbers are referred to throughout the text of the survey results. Individual anomalies within a cluster are indicated on Figure 3 by lower case alphabetic characters (a, b, c, etc.). Reference in the text to a specific anomaly within a cluster is by number and letter (e.g., 5d at the bow of

King Philip). The composition of the riprap is correlated with the resulting anomaly patterns along the lower margin of Figure 3. A detailed description of the riprap's magnetic effects is provided in the following section.

Visible Anomaly Sources

As was suspected prior to conducting a magnetic survey of the project area, visible anomaly sources associated with the riprap-covered slope have complicated the interpretation of magnetometer data from the upper portion of the beach. The most predominant visible source of anomalies in the project area is the jumbled assortment of concrete and stone which was used for riprap on the slope below the Great Highway. Other visible sources include: the steel-reenforced concrete pavement of the Great Highway, the steel guard rails and steel-reenforced concrete traffic barriers which border the highway along its entire length through the project area, the West Side Transport wastewater main which is buried in the dunes beneath the highway, and the car and truck traffic which traveled along the highway throughout the course of the survey. Less likely sources which were also recorded during the survey include: the remains of intact beach hearths, timbers with iron fastenings lying on the beach, and pilings or other timbers protruding from the beach. Correlation of magnetic contour signatures with visible anomaly sources allowed for the exclusion of a large number of magnetic signatures from consideration as having possible cultural significance. The results of this analysis are discussed separately below for each category of visible anomaly source observed. Analysis of the contoured data, illustrated in Figure 3, indicated that an additional source of magnetic anomalies, which should be considered in the future but which was not accurately mapped during the current study, is the sharp topographic relief of beach cusps associated with the high tide line. Further discussion of beach cusps and berms as potential sources of magnetic anomalies can be found in a later section.

Riprap

The magnetic effect of the riprap is one of the most noticeable features of the magnetic contour map (Figure 3). The riprap material consists primarily of concrete rubble which, judging from the size and thickness of the slabs, is the remains of road pavement. Other materials which occur in lesser amounts on the slope include granite building stones, dark-green boulders of pyroxene-rich igneous rock, and small pieces of blacktop pavement. Prior to conducting the survey, the potential magnetic effects of iron reenforcement bar in the concrete riprap was a major concern, due to the possibility that it might mask the presence of significant anomalies located beneath or adjacent to the slope. Close inspection of the slope, however, revealed that very little of the concrete used as riprap is reenforced with iron. Although the concrete itself can be expected to produce an anomaly, due to the use of igneous gravel as a temper, the net magnetic effect is expected to be relatively small, in comparison to that of iron bar, as the random orientation of the individual pieces of gravel in concrete should cause them to cancel one another out. It was apparent, following the survey of our first few transects, that the magnetic effect of igneous materials in the riprap was a major concern. These materials have, by far, the highest magnetic intensity of the materials known to comprise the riprap.

Following completion of the magnetometer survey, a visual inspection of the entire slope was conducted, in order to allow later correlation of anomalies with possible sources visible on its face. The results of this inspection are summarized along the lower margin of Figure 3. It can be seen from Figure 3 that there is a close association between the presence of igneous materials in the riprap or at the base of the slope and the areas of highest magnetic gradient along the upper beach. For example, the portion of beach from N 100 to N 858 has the highest concentration of igneous materials in the riprap of any area and has a correspondingly high magnetic gradient. Similarly, the area extending south from N 725 to N 680 has igneous boulders visible in the riprap, though in lesser amounts, and has several correspondingly large anomalies at the base of the slope. On the other hand, there are areas where high magnetic gradients occur on the upper portions of the beach which have no apparent cause in visible sources. One such area occurs at the base of the slope in Area C. Another extends midway onto the beach throughout all of Area F. The cause of these high-gradient areas is hypothesized to be due to igneous materials buried beneath the surface riprap or, in the latter case, to igneous materials which may have tumbled down from the slope and become buried in the beach.

Great Highway

The magnetic effects of the Great Highway, of the guardrail and traffic barriers which line its course, and of the West Side Transport wastewater tunnel which is buried in the dunes beneath the highway are considered negligible in comparison to those of more local sources, such as those occurring in the riprap. The composition and orientation of the Great Highway throughout the length of the survey area is constant; thus, its magnetic effects can be expected to be uniform. For example, the highway and associated features may contribute to the overall trend of decreasing magnetic intensity as one moves closer to the surfline. Were it not for the proximity of highly magnetic materials in the riprap, it should be possible to detect anomalies resulting from local sources against the relatively uniform magnetic gradient expected from the Great Highway.

Traffic

The effects of vehicle traffic on the quality of the magnetic data were initially considered to be a potential problem. Not only was it feared that passing traffic would result in anomalies which were not reflective of materials buried in the beach, but also that traffic would be detected by the base-station sensor, making the base-station data useless for the purposes of diurnal correction. This problem was alleviated by positioning the base station sensor at least 130 feet west of the highway throughout the course of the survey. It was not possible, of course, to maintain this distance from the highway with the portable magnetometer. When standing at the base of the riprap, the nearest traffic lane was generally not more than 30 feet from the sensor. Breiner (1973:46) indicates that a 1-ton automobile passing at a distance of 30 feet may be expected to produce a 40-gamma anomaly. The effects of traffic on the portable sensor were minimized, however, by use of a three-reading-average mode available on the G-856 magnetometer. In this mode, the magnetometer takes three readings over a period of approximately five seconds and stores the average of these readings in its internal memory. The five-second sample interval allows time for traffic to pass to a safer distance before all readings are taken. When surveying portions of the slope, the sensor was positioned immediately adjacent the highway. Due to our elevated position on the slope, however, it was possible to see oncoming traffic and avoid taking readings at these times.

Beach Hearths, Timbers and Pilings

During the course of the survey, all potential anomaly sources on the surface of the beach were recorded, including the intact remains of beach hearths, timbers with iron fastenings, and pilings protruding from the sand. In the case of pilings, it was considered possible that they may be the remains of a former structure, such as a pier, which could produce an anomaly, should some portion remain buried in the beach. Correlation of surface features with the magnetic contours at these locations was conducted on a working copy of Figure 3. The results indicated that in no instances were anomalies, which might otherwise be interpreted as potentially significant, associated with pilings protruding from the beach or with magnetic materials on the surface of the beach.

Non-visible Anomaly Sources

One of the most outstanding features of the Ocean Beach magnetometer data is the large number of anomalies. The magnetic contours of Figure 3 cannot be described as anything but convoluted and complex. The following interpretations of these data are based upon our expectations for anomaly patterns resulting from environmentally exposed shipwrecks, as summarized in Chapter IV, in combination with our knowledge of the King Philip and Reporter sites and their associated anomaly patterns, and with the aid of historic references. The descriptions which follow are organized by major area of interest, as delineated along the upper margin of Figure 3, beginning with Area A which encompasses the King Philip and Reporter wreck sites. Unless otherwise specified, the remainder of Chapter V refers to Figure 3. Numbers appearing in parentheses ( ) throughout Chapter V correspond to numbered magnetic anomalies on Figure 3.

Area A

The anomaly patterns of the King Philip and Reporter wreck sites are clearly visible within Area A. The location of the King Philip was mapped by archaeologists affiliated with the National Park Service during a recent exposure of the vessel in 1983. The outline of the King Philip's hull has been superimposed on Figure 3a in order to emphasize the relationship between hull size and shape and the resulting multi-peaked linear anomaly cluster. The position of the King Philip's bow (north end of vessel) and the length of her hull were plotted on the basis of physical measurements made during the 1983 exposure of the vessel. The orientation of the hull was originally mapped as indicated by the dashed line shown extending southeastward from the bow; however, photographs of the exposed hull indicate that her true alignment is parallel to the axis of the associated anomaly pattern. At the time that the King Philip was mapped, the stern had already been reburied by accretion of sand on the beach; therefore, it was not possible to accurately measure the distance between the stern and the GGNRA line, as was done when plotting the bow location. Instead, the hull orientation was mapped on the basis of a hand-held compass heading, taken along the axis of the vessel while the stern was exposed. The presence of a large magnetic anomaly at the bow, however, caused a clockwise deflection of the compass needle, resulting in an incorrect plotting of the vessel orientation.

Historic accounts of the Reporter wreck indicate that the vessel was situated, immediately prior to breaking up, with its stern lying next to the bow of the King Philip and its bow pointed out to sea but angled slightly northward. The positions of the Area A anomalies at 3b and 3c correspond with this description. In all probability, these two anomalies, in combination with Anomaly 3a, represent the major extant portions of the Reporter's hull. Other anomalies which may represent extant portions of the Reporter and/or King Philip are located at 1, 2 and 4. Numerous small anomalies, indicated by + and - signs, occur interspersed throughout the wreck sites. These may be associated with scattered wreckage of either vessel, including the wire rigging from Reporter which was found, during recent exposures, to be intermingled with wreckage from the King Philip.

Area B

The most prominent feature of this area is a "plateau" of high magnetic intensity, corresponding to the darkly shaded portion of Area B (Figure 3b). This area of elevated magnetic field extends inland from the surf, nearly to the base of the riprap. At the surf, the beginnings of a broad, high-gradient anomaly (7) can be seen. The full extent of Anomaly 7 is not located within the survey area; nevertheless, the overall pattern formed by the anomalies at 7, 8, 9, and 11 bears a strong resemblance to the expected pattern of a buoyant hull fracture site. The apparent beginnings of a high magnetic gradient can also be seen at 10; however, a relationship between 7 and 10 cannot be demonstrated. The anomaly at 12b may be associated with the larger Area B pattern or with the less distinct pattern of Area C, described below. The dashed line which crosses the beach at the center of Area B is the boundary between the areas of 6- and 12-foot survey grid spacing.

Area C

The most interesting feature of Area C (Figure 3b) is the presence of medium-intensity anomalies (ranging from 60 to 100 gammas) arranged in a multi-peaked, linear pattern (at 12, 14, and 16) which is oriented parallel to the surfline. Taken by itself, the anomaly cluster at 14 somewhat resembles the anomaly pattern of a buoyant hull wreck, such as the King Philip, although less uniform in shape and of lower magnetic intensity. When viewed as part of a larger pattern, including anomalies at 12 and 16, the overall pattern more closely resembles what might be expected from an arrangement of disarticulated wreckage washed up along a strandline. A good example of flotsam scattered along a strandline can be seen in a photograph of the Aberdeen wreck site (Figure 17). The sources of these anomalies cannot be known, short of conducting test excavations; however, the resemblance of the overall anomaly pattern, in orientation and intensity, to that which might be expected from strand line wreckage, in combination with their position midway between two suspected wreck sites, suggests a high probability that they may be historically significant. Anomalies at 13 and 15 should also be included in this category by reason of association.

Area D

Aside from the King Philip and Reporter wreck sites, Area D (Figure 3c) holds the greatest potential of any area within the boundaries of the survey for containing historically significant wreckage. As was the case with Area B, the orientation of the darkly shaded magnetic field "plateau" in Area D (anomalies 17 to 22) is consistent with that expected from a buoyant-hull fracture site. The anomaly pattern of Area D even more closely resembles a wreck site than does the pattern of Area B, in that the "plateau" contains multiple peaks similar to those observed at the Reporter and King Philip wreck sites.

It is probable that the anomaly pattern described above is caused by the partially articulated remains of the Atlantic's hull. Historic research conducted by the staff of the National Park Service (Delgado 1987) indicates that the whaler came ashore approximately 1,000 feet south of the King Philip. The center of the large anomaly at 17 is located 1,032 feet south of the King Philip's stern. This position and the resemblance of Anomaly 17 to the bow anomaly of King Philip (5d) suggest the possibility that Anomaly 17 may be associated with the bow of the Atlantic. From the historic reconstruction of the wreck event (Chapter III), we know that the Atlantic came onto the beach stern-first, dragging both anchors. The San Francisco Daily Examiner of 18 December 1886 stated that the bow was "well out in the foaming breakers", the anchor chains and bobstays dangling from the fractured bowsprit, while "the stern lay at about the extreme limit reached by the dying waves." Having wrecked in mid-December when the beach is generally narrow, it is conceivable that scattered wreckage was carried at least as far up onto the beach as was the hull of the King Philip, the latter having wrecked in January. Anomalies 18 through 22 are also believed to be associated with intact portions of the Atlantic's hull. Although the anomalies at 22 may alternatively be caused by buried igneous boulders, known to comprise a part of the riprap along this section of beach, it is possible that the high gradient of these anomalies could mask the signature of weaker anomalies associated with significant portions of wreckage. The anomalies at 22 should, thus, be considered sensitive with regard to the potential for historic resources.

Portions of areas C and D were resurveyed at a 6-foot grid spacing, in order to increase the data resolution over the suspected location of the Atlantic to that obtained for the King Philip and Reporter. The area resurveyed is delineated by a heavy dashed line in figures 3b and 3c. The resurvey of this area was accomplished by taking magnetometer readings only at those grid intersections which were not part of the initial 12-foot survey. The data obtained by this method has been plotted at a 10-gamma contour interval in Figure 18. In retrospect, it would have required less time to resurvey every data point in these areas, as meshing of the data sets to create an acceptable line-contour plot required a considerable amount of additional data manipulation. By the same token, the increased resolution did little to change our perception of this area as being a probable wreck site.

Area E

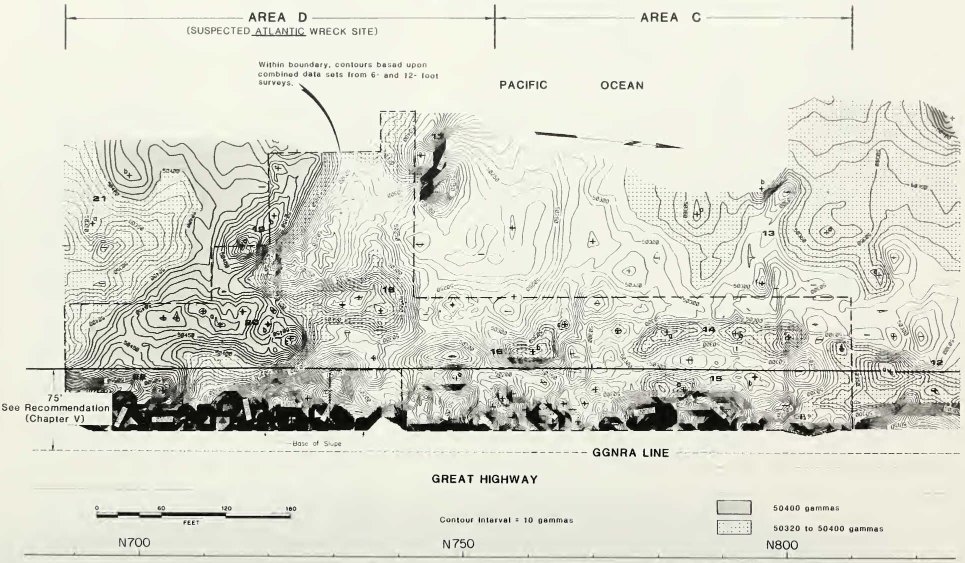
This portion of the beach (Figure 3c) appears to be very clean, magnetically speaking. The only anomaly of suspected historic origin is located along the surfline at 23. Of particular interest, however, is a line of weak anomalies (24a-d), situated just beyond the middle of the beach and oriented parallel to the surfline. Notice the consistent orientation and fairly even spacing of the +/- pairs. The location of this pattern corresponds to a series of steep beach cusps which formed the undulating line of the high tide at the time of the survey. These anomalies were apparently caused by the magnetic effects of the beach sand along the sharp topographic break of the berm.

Area F

The primary feature of interest in Area F (Figure 3d) is the large linear-shaped pattern of consistently high magnetic field gradient, occurring adjacent the base of the riprap and extending midway out onto the beach. The magnetic intensity of this area, relative to the estimated normal total field intensity for the beach (approximately 50,320 gammas), is significantly higher than that of anomalies associated with the King Philip and Reporter wreck sites. The largest anomaly recorded in the latter area (excluding the riprap) is approximately 240 gammas, whereas the

Figure 18

RESURVEY OF SUSPECTED ATLANTIC WRECK SITE AND ADJOINING AREAS


AREA D
(SUSPECTED ATLANTIC WRECK SITE)
AREA C
Within boundary, contours based upon combined data sets from 6- and 12- foot surveys.
PACIFIC OCEAN
21
19
20
18
17
16
15
14
13
12
22
50400
50350
50300
50250
50200
75'
See Recommendation (Chapter V)
Base of Slope
GGNRA LINE
GREAT HIGHWAY
0
60
120
180
FEET
Contour Interval = 10 gammas
50400 gammas
50320 to 50400 gammas
N700
N750
N800

intensities of the higher anomaly peaks in Area F range from 220 to 520 gammas with horizontal gradients as high as 30 gammas per foot. This approaches the intensity and gradient of anomalies caused by igneous boulders at the foot of the riprap in Area B; however, as can be seen from Figure 3d, there is very little igneous rock visible on the slope in Area F. Although igneous material may be concealed by the riprap or beneath the base of the slope in Area F, it is considered more likely that the high gradients in this area are caused by buried materials, located further out on the beach. This conclusion is based upon the fact that anomaly peaks in Area F are situated further out on the beach (42 to 48 feet out from the base of the riprap) than are those associated with the igneous boulders of Area B (12 to 18 feet). While it is possible that material from the riprap may have tumbled onto the beach and become buried, it is believed that the production of such a large area of high gradient, as is observed in Area F, would require at least as much igneous material as is present on and adjacent the slope in Area B.

It is the opinion of the principal investigator that the overall linear pattern of high gradient anomalies observed in Area F is not caused by the presence of intact shipwreck elements. The extreme high intensity of these anomalies, combined with the large horizontal extent of their combined distributions, bears little resemblance to the anomaly patterns of the King Philip and Reporter wreck sites. Potentially significant exceptions, however, are the anomalies at 26, 27 and 29, all of which deviate from the otherwise linear pattern of Area F. This is especially true when viewed in relation to the anomalies at 25 and 28. The latter anomalies are more characteristic, in horizontal extent and intensity, of what might be expected from the scattered wreckage of a buoyant-structure site, such as that of the Aberdeen.

Anomaly Source Depth Estimates

Vertical gradient measurements were made on 12 selected anomalies during the course of the survey. These anomalies were chosen based upon a preliminary examination of magnetic field profiles (e.g., Figure 14) for each survey transect. Depth estimates have been calculated using both the monopolar and dipolar fall-off factors, discussed in Chapter IV, and are presented in Table 1, the dipolar calculation being the larger of the two figures in each case. Determining which of the two depth estimates might be more accurate for a given anomaly requires a judgement call in each case. Breiner points out that, if the "object of search is relatively small with respect to the distance between it and the magnetometer, ...the object would then behave as a magnetic dipole" (1973:39). On the other hand, an intact section of a ship's hull would comprise a rather broad source (in terms of horizontal area) with respect to the distance between it and the magnetometer sensor. Thus, for relatively distinct dipolar anomalies, such as 5d, the actual depth to the source may be more closely approximated by the larger of the two depth estimates, while for anomalies which lack a well-defined negative component, for example, 5b or 5c, the shallower of the two depths may be more realistic.

TABLE 1

ANOMALY SOURCE DEPTH ESTIMATES:

VERTICAL GRADIENT METHOD

Anomaly	Coordinates	Intensity in Gammas	Vertical Gradient	Depth for Monopole	Depth for Dipole
2a	N 953 / W 111	170	26.2	7.0′	13.5′
2b	N 959 / W 114	130	36.6	1.1′	4.7′
5b	N 928 / W 119	180	4.3	77.7′	119.6′
5c	N 937 / W 121	210	9.8	36.9′	58.3′
5d	N 943 / W 119	220	32.2	7.7′	14.5′
14c	N 800 / W 106	80	28.5	-0.4′	2.4′
15a	N 784 / W 98	70	43.2	-2.8′	-1.1′
16b	N 761 / W 104	70	19.9	1.0′	4.6′
19a	N 719 / W 120	190	22.2	11.1′	19.7′
20c	N 725 / W 106	160	22.5	8.2′	15.3′
22b	N 696 / W 98	300	23.8	19.2′	31.8′

A more detailed analysis of the magnetic data, following field work, resulted in the identification of several additional anomalies for which vertical gradient data would have been desirable. As this data was no longer available, depths for these additional anomalies have been estimated, where possible, using the slope method described in Chapter IV. Fifteen anomalies were selected for estimation of source depth using the slope method (Table 2). Based upon Breiner (1973:28), the figures given in tables 1 and 2 are believed to represent maximum depth estimates for the sources in question.

Source depth was estimated for four anomalies (2b, 5b, 5d and 19a) using both the slope technique and the vertical gradient method. Actual source depth is known for only two of these anomalies, 5b and 5d, which overlie the hull of the King Philip. Based upon information from beach profiles, the top of King Philip's hull is known to have been 8 to 11 feet below the beach surface at the time of the survey. Hydraulic probing of the exposed hull in 1983 indicated at least 10 feet of extant hull below the surface (Delgado 1985b). As the King Philip is a complex anomaly source, the source depth estimates for anomalies 5b and 5d are expressed as a range, between 8 and 21 feet, with the first value being the minimum depth to the top of the hull and the second value being the maximum lower limit of the source.

Depth estimates calculated for anomalies 5b and 5d (Table 2) using the slope technique are in close agreement with the 8- to 21-foot range for the depth of the King Philip. Vertical gradient estimates for 5b and 5d (Table 1) are much less consistent, although the dipolar estimate of 14.5 feet for anomaly 5d falls precisely at the middle of the depth range estimated by the slope technique. Source depths calculated by the vertical gradient method for anomalies 5a and 5b (Table 1) vary widely from the known depth range. Based upon the results of source depth estimates for anomalies over the King Philip, it is inferred that the slope technique is a more consistently reliable method for estimating the depth to complex sources than is the vertical gradient technique.

When assessing the potential accuracy of depth estimates, using any method of estimation, some consideration must be given to realistic expectations regarding the nature of the source or sources which may be causing a particular anomaly. For example, it may not be possible to accurately estimate source depth for anomalies having suspected diffuse or multiple sources. It must be emphasized that methods of anomaly source depth estimation are designed for application under ideal conditions in which anomalies are caused by simple, compact sources, without the confusion of multiple-source effects. While there are certain limitations in the use of techniques for source-depth estimation in cultural resource planning, there are also at least two important advantages. First, although there is a certain amount of latitude in the range of depth estimated for any given anomaly, when applied selectively to well-defined anomalies, such techniques can increase the level of confidence that a source is located at a depth which may contain historically significant material. In the vicinity of the King Philip wreck site, for example, it is unlikely that anything of historical significance would be located

TABLE 2

ANOMALY SOURCE DEPTH ESTIMATES: SLOPE METHOD

Anomaly	Coordinates	Intensity In Gammas	Depth Estimate
1	N 967 / W 140	100	9′
2b	N 959 / W 114	130	9′
5b	N 928 / W 119	180	15′
5d	N 943 / W 119	220	12′
8	N 861 / W 116	80	12′
9c	N 865 / W 104	120	15′
12b	N 830 / W 108	60	9′
13c	N 795 / W 114	40	9′
13e	N 813 / W 115	30	12′
16b	N 761 / W 104	60	3′
17	N 744 / W 133	160	9′
19a	N 719 / W 120	210	12′
23	N 646 / W 131	120	6′
25	N 604 / W 111	240	15′
26	N 597 / W 103	380	27′

within the upper 8 feet of sand (at the time of the survey), as the beach has fluctuated in elevation by at least this much within the last five years. Second, it is only by making such attempts and then testing the results that our level of confidence with such techniques, as applied to archaeological sites, will increase.

Recommendations

Magnetic anomalies or anomaly clusters, identified above as being potentially caused by historic wreckage, should be avoided, if possible, during this and all future construction projects. Earth moving in the immediate vicinity of any such anomalies should be preceded by some form of archaeological testing, in order to verify whether historically significant materials are present. Archaeological verification of anomaly sources could be accomplished most expeditiously through a combination of magnetic prospection, hydraulic probing and mechanical trenching (see Chapter VI). Anomalies to be tested should first be resurveyed with a magnetometer in order to precisely locate their points of highest and lowest magnetic field intensity. Second, hydraulic probing at evenly spaced grid intervals along an anomaly's polar axis could be conducted to pinpoint the location of potential anomaly sources. Third, assuming that a buried object was contacted by probing, test excavations could then be conducted with the confidence that they could be slowed or halted prior to contacting the source, thus preventing damage of potentially significant remains. Should hydraulic probing fail to locate a potential anomaly source within the depth of expected impacts, no further consideration of the anomaly in question should be necessary.

A secondary benefit stemming from an archaeological testing program at Ocean Beach would be the value of the results for improving the accuracy of future data interpretations in similar environments. A shortcoming of many magnetometer surveys has been the lack of anomaly source verification. It is only through testing of our interpretive skills that we refine the accuracy of subsequent archaeological interpretations. Likewise, refinement of interpretive models and techniques may increase the effectiveness of remote-sensing surveys for use in cultural resource management, with the result that more effective testing strategies may be formulated, both in terms of cost and of the information retrieved.

More specific recommendations are provided below for potentially significant areas which might be impacted by seawall construction, either during current or future construction phases. These recommendations are prioritized in descending order of their suspected potential for historical significance. The Clean Water Program has demonstrated, to the satisfaction of GGNRA and NPS, that construction impacts to NPS property will occur only within the first 40 feet west of the GGNRA line. Due to the magnetic effects of the riprap, however, it was not possible to delineate potentially significant anomalies within this zone, except by association with anomaly patterns located farther out on the beach. The following recommendations, therefore, assume that areas having potential wreck signatures within 75 feet of the GGNRA line may also contain significant anomalies within 40 feet of the line, even though such anomalies were not discernible from the magnetic effects of the riprap during the original survey. The western limit of this 75-foot-wide zone of recommendations is shown on figures 3 and 18 as a solid line, west of and parallel to the GGNRA line.

Anomalies 22a, 22b, and 22c

The sources of these anomalies are suspected to be associated with the remains of an historic shipwreck, believed to be that of the whaling bark Atlantic. The presence of igneous boulders in the riprap along this section of beach may, however, be expected to have an effect upon the location of these anomalies with respect to their underlying sources. Although these anomalies are located primarily outside of the 40-foot-wide impact zone, it is emphasized that their sources are expected to be complex and may extend well beyond the horizontal limit of the anomaly peaks (compare, for example, the distance between the anomaly peaks of the King Philip and the edge of her hull (Figure 3a)). Archaeological test excavations were strongly recommended in the draft survey report. Concurrence by the SHPO and NPS with this recommendation resulted in further investigation of this area (see Chapter VI).

Anomalies 11a and 11b

These anomalies may be associated with the remains of a wrecked vessel hypothesized to be present in Area B. Suspicion that these anomalies may be significant is strengthened by two factors: a) they are situated adjacent to a "plateau" of high magnetic intensity, observed in Area B, which is believe to be caused by the remains of a buoyant hull fracture site; and b) they are located along a portion of the riprap which has no visible source of such high intensity anomalies. Archaeological verification is strongly recommended.

Anomalies 9b and 9c

Both of these anomalies are suspected to be associated with the remains of a wrecked vessel of unknown origin. Should testing of either one of these anomalies verify the presence of vessel remains, it is strongly recommended that anomaly 9a also be tested. An historic assessment of any wreckage which may be encountered would be dependent upon the presence of diagnostic elements which might indicate the vessel's identity and/or period and/or function.

Anomalies 12a, 14c, 15a, 15b, 16a and 16b

These anomalies are believed to be caused by a scatter of wreckage washed ashore along a strandline. It is conceivable that this material is associated with the remains of more than one vessel. Two possibilities are, of course, the Atlantic and the Aberdeen. Should testing of these anomalies verify the presence of scattered, disarticulated wreckage, similar to that observed along the strandline in Figure 17, it is unlikely that the identity or type of the vessel(s) could be determined without first establishing the identities of the vessels suspected to have wrecked in areas B and D.

Anomalies 26 and 30

These two anomalies are believed to have the highest potential for association with buried wreckage in Area F, as both represent deviations from the regular, linear anomaly pattern observed here. Although Anomaly 26 is centered slightly more than 75 feet west of the GGNRA line, it is again stressed that a complex source, such as a wooden-hulled vessel, may extend well beyond the resulting anomaly's center. Should the sources of either of these anomalies be determined historically significant, other anomalies associated with the linear pattern of Area F should also be tested. Likewise, should testing fail to identify a source for either of these anomalies, at least one additional anomaly from Area F should be selected for testing, in an attempt to determine the source of this anomaly pattern.

CHAPTER VI
APRIL 1988 MAGNETIC SURVEY AND TEST EXCAVATIONS ON THE SUSPECTED ATLANTIC WRECK SITE

In April, 1988, EH&A returned to Ocean Beach to conduct further archaeological investigations in the suspected vicinity of the Atlantic wreck site. Based upon the magnetometer survey results and recommendations, reported in Chapter V, the archaeological staff of the NPS, Western Region, recommended that an area surrounding anomalies 22a, 22b and 22c (Figure 19) be resurveyed following removal of the riprap and underlying sand dunes. Although several other anomalies were recommended by EH&A for further investigation (Chapter V), the section of seawall currently contracted for construction will not impact those areas. The impetus for resurveying the selected area was to determine whether the anomaly pattern of the suspected Atlantic wreck site extends into the construction zone beneath the sand dunes. This could not be determined from the original survey data, due to the presence of highly magnetic materials in the riprap. It was hoped that, by removing these visible anomaly sources and then resurveying the area, we would be able to discern the presence or absence of buried wreckage within the impact zone. Potentially significant anomalies identified by the magnetometer survey would then be subjected to archaeological test excavations.

The area selected for further investigation (study area) is bordered on the east by the GGNRA line and on the west by the W 100 baseline from the fall 1987 magnetometer survey grid (figures 19 and 20). The northern and southern boundaries are formed by lines extending perpendicularly from the GGNRA line at N 720 and N 660 on the 1987 survey grid (56+85.62 feet north and 53+25.63 feet north, respectively, on the "C"-Line). The positions of anomalies 22a, 22b and 22c are indicated in the western portion of the work area (Figure 19), just beyond the limit of the 40-foot-wide zone of construction impacts.

Construction of the seawall will require excavating portions of Ocean Beach beneath the riprap and underlying sand dunes (Figure 20). The base of the seawall will extend to a depth approximately 30 feet below the normal beach level. The western limit of impacts due to excavation will be approximately 7 feet west of the GGNRA line. The temporary sheetpile shown in Figure 20 will be driven into the beach, prior to excavation, approximately 4 feet west of the GGNRA line, and a 3-foot zone west of this will be used for the placement of dewatering wells. Additional beach disturbances are possible up to 40 feet west of the GGNRA line, due to the use of heavy machinery on the beach during construction.

Prior to entering the field for the testing phase, the riprap and underlying sand dunes were mechanically removed from the study area, as

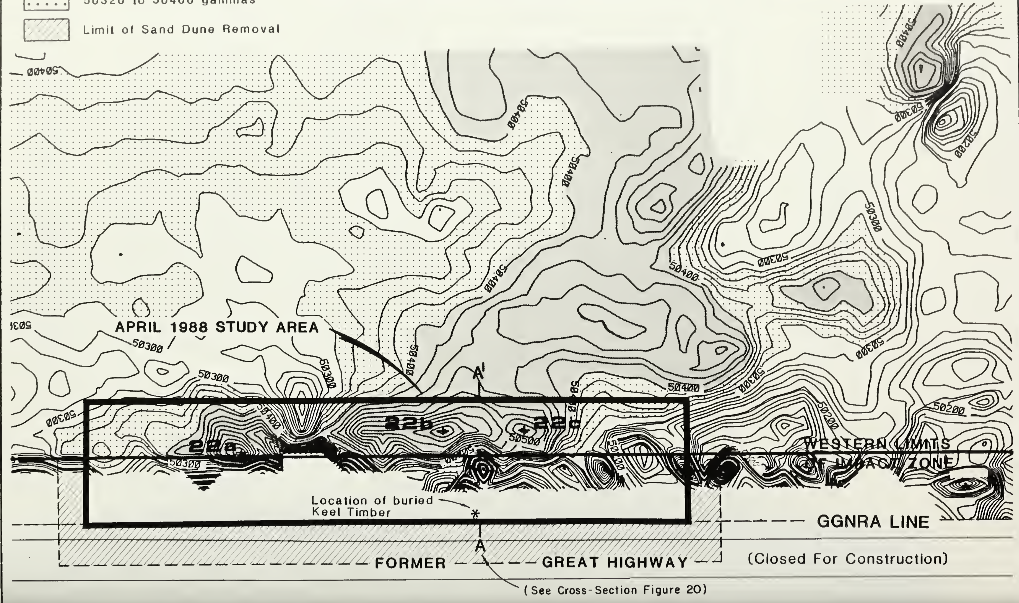


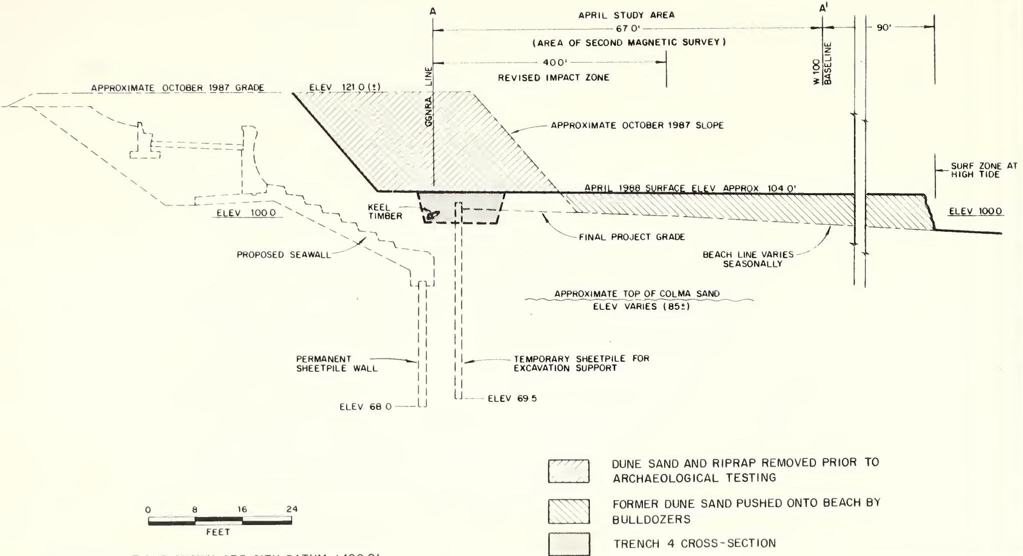
Figure 19

SUSPECTED SITE OF THE ATLANTIC WRECK
SHOWING AREA OF 1988 INVESTIGATIONS

▨ 50400 gammas (Suspected Distribution of Intact Wreckage)
⠿ 50320 to 50400 gammas
▨ Limit of Sand Dune Removal
0
60
120
FEET
Contour Interval 20 gammas
APRIL 1988 STUDY AREA
22a
22b
22c
A'
A
50300
50400
50500
50200
WESTERN LIMITS OF IMPACT ZONE
Location of buried Keel Timber
GGNRA LINE
FORMER GREAT HIGHWAY
(Closed For Construction)
(See Cross-Section Figure 20)

Figure 20

VERTICAL CROSS-SECTION OF BEACH AND PROPOSED SEAWALL AT TEST TRENCH 4


A
A'
APRIL STUDY AREA
67 0'
(AREA OF SECOND MAGNETIC SURVEY)
400'
REVISED IMPACT ZONE
90'
W 100 BASELINE
GGNRA LINE
APPROXIMATE OCTOBER 1987 GRADE
ELEV 121 0 (±)
APPROXIMATE OCTOBER 1987 SLOPE
SURF ZONE AT HIGH TIDE
APRIL 1988 SURFACE ELEV APPROX 104 0'
ELEV 100 0
ELEV 100 0
KEEL TIMBER
FINAL PROJECT GRADE
PROPOSED SEAWALL
BEACH LINE VARIES SEASONALLY
APPROXIMATE TOP OF COLMA SAND
ELEV VARIES (85±)
PERMANENT SHEETPILE WALL
TEMPORARY SHEETPILE FOR EXCAVATION SUPPORT
ELEV 69 5
ELEV 68 0
DUNE SAND AND RIPRAP REMOVED PRIOR TO ARCHAEOLOGICAL TESTING
FORMER DUNE SAND PUSHED ONTO BEACH BY BULLDOZERS
TRENCH 4 CROSS-SECTION
0
8
16
24
FEET

NOTE: ELEVATIONS SHOWN ARE CITY DATUM ±100.0' indicated by hatching in figures 19 and 20. The eastern extent of the contour lines in Figure 19 defines the base of the riprap as it existed in October 1987. The riprap material was removed from the top of the slope by means of a backhoe. Removal of the underlying dune sand was also accomplished by means of a backhoe; however, in the latter case, the sand was pulled down from the base of the slope, then spread out across the beach using bulldozers.

Following removal of the dune and riprap overburden, surveyors from the City of San Francisco's survey division marked each corner of the study area by placing wooden laths in the beach and provided EH&A with elevations for these points. The surface elevation of the study area was slightly above the natural level of the beach, due to the displacement of dune sand onto the beach. This sand will be left in place during construction of the seawall, except in the area to be excavated for placement of the seawall footings (Figure 20), thus providing a sand buffer over the western portion of the study area. This buffer should alleviate potential impacts to buried wreckage which might otherwise have resulted from heavy machine traffic in this area. Throughout the course of the year, this sand will be leveled by the sea, providing a source of beach nourishment.

On April 6, a magnetometer survey was conducted of the study area (outlined in Figure 19). The survey was conducted by the same procedures as the original survey (Chapter IV). An EG&G Geometrics Model G-856 proton precession magnetometer was used as a survey instrument and a Model G-866 magnetometer as a base station instrument. Magnetometer readings were recorded at evenly-spaced 6-foot grid intervals. The G-856 sensor was deployed at a height of 6 feet. Base station readings were recorded at 5-second intervals throughout the course of the survey using a sensor height of 4 feet. Diurnal corrections were performed using EG&G Geometrics' Magpac computer software package. Upon completion of the magnetometer survey, the magnetic data was mapped using this same software package. A variable density, dot-matrix contour map of the data was plotted for the entire survey area, as were line-graph plots of the data from each survey transect.

Once a number of anomaly locations had been selected for testing and their locations marked on the beach, each was subjected to hydraulic probing, in an attempt to pinpoint the depth and horizontal extent of each source prior to its excavation (Figure 21). A ten-foot section of 3/4-inch PVC pipe connected to a water hose was used as a probe. Due to the high energy of the surf zone, it was not possible to use the ocean as a water source; therefore, a water truck, provided by the Clean Water Department, was parked at the top of the slope and used for this purpose. Probing was conducted on a grid surrounding each anomaly location for a distance of approximately four feet on all sides. Generally, at least 25 probes were made at each anomaly location with a spacing between probes of approximately two feet.

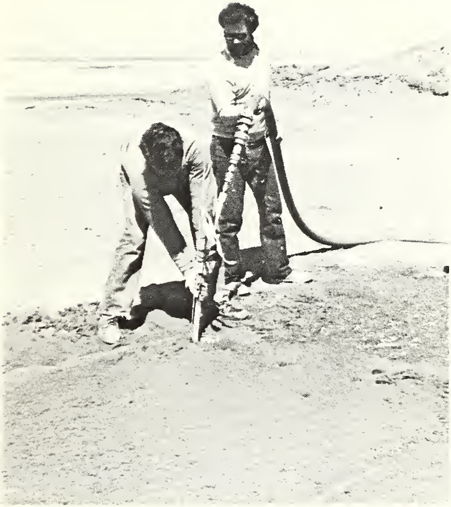


Figure 21. Hydraulic probing of magnetic anomaly to locate its source.

An examination of the preliminary survey results indicated the presence of 32 suspected anomalies within the 40-foot impact zone. Based upon this information, a field decision was made, in consultation with Roger Kelly of the NPS, to test a sample of the anomalies, and locations were selected for five test trenches, so as to maximize the number of anomaly sources which could be investigated. Trenches were excavated using a D-5 Caterpillar bulldozer with an experienced operator (Figure 22). Sand was removed from the trenches in approximately 6-inch layers with each pass of the D-5. By making repeated passes, the trenches were gradually deepened until an anomaly source was encountered or until attaining the desired depth. Excavation was continuously monitored by EH&A's archaeological field crew with the assistance of Roger Kelly, regional archaeologist for the NPS, Western Region.

A subsequent and more comprehensive analysis of the data, including examination of a magnetic line-contour map, revealed that several anomalies which had been tested were uncharacteristic in appearance. Typically these anomalies were high-intensity monopoles (700 gammas or more) which were detected on only one survey station, whereas, most anomalies can be expected to be dipolar, due to the relatively small size of potential sources with respect to their distance from the sensor (e.g., Figure 3 and Breiner 1973:39), and should appear on more than one station. For example, if we assume a 6-foot sample spacing and a 6-foot sensor height, it can be estimated that a dipolar anomaly of as little as 60 gammas should appear on at least one adjacent station as an anomaly of 20 gammas or more (Breiner 1973:24). Based upon this knowledge and upon a closer inspection of each anomaly, it was concluded that 28 of the anomalies previously identified within the impact zone were spurious readings and do not indicate the presence of buried ferrous objects.

Experimentation with the G-856 used during the survey indicated that high-magnitude, spurious readings resulted from excessive sensor motion. Based upon an examination of the magnetometer and upon consultation with the manufacturer, this problem has been attributed to instrument tuning. Spurious readings in the data set were subsequently replaced with averages of the nearest surrounding values. The corrected results were then replotted on EH&A's Intergraph computer system as a magnetic line-contour map (Figure 23a-c). Consistency between the magnetic profiles of adjacent survey transects verified that only a small percentage of the 732 total readings were affected. This problem was not encountered during the 1987 magnetometer survey.

RESULTS

Magnetic Survey

A total of 732 data points were sampled during the course of the magnetic survey. A magnetic line-contour map of the survey results is illustrated in Figure 23. The data set represented in Figure 23 has been revised to exclude spurious readings resulting from tuning problems, thus

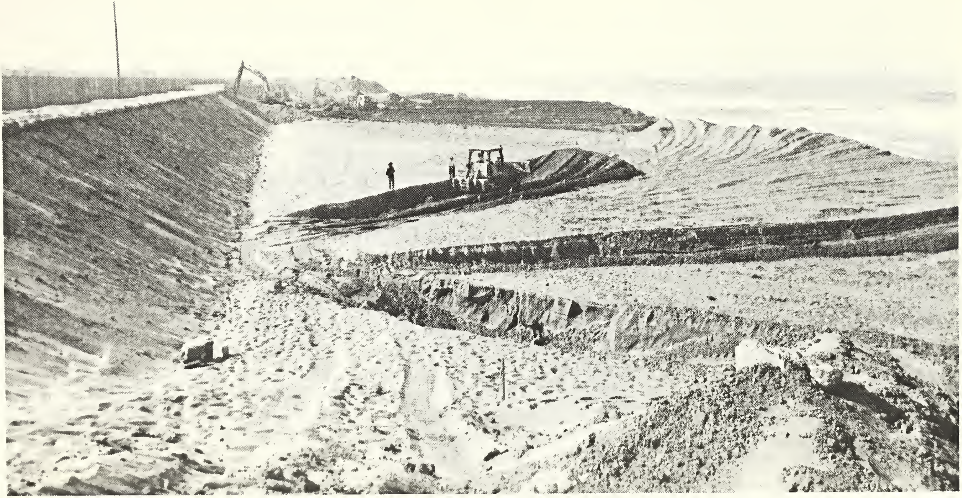


Figure 22. Mechanical test excavations using D-5 caterpillar (foreground). Notice ongoing seawall construction in background.

Figure 23

INDEX MAP FOR FIGURES 23a - 23c

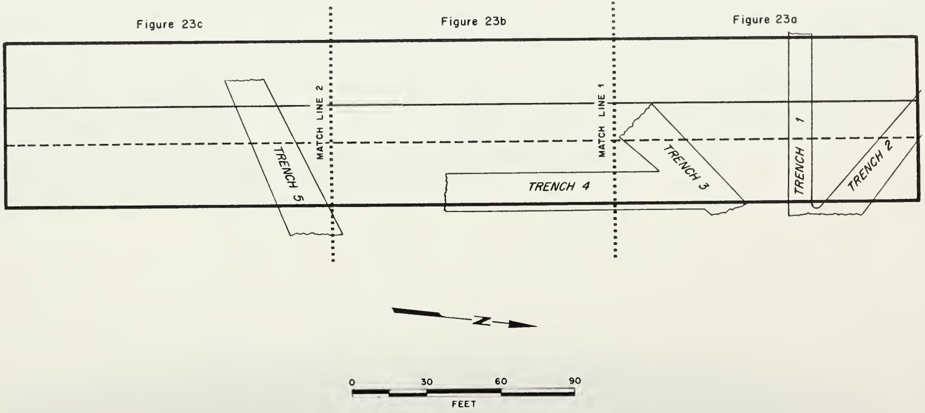


Figure 23a

MAGNETIC CONTOUR MAP AND TEST TRENCHES
APRIL 1988 STUDY AREA

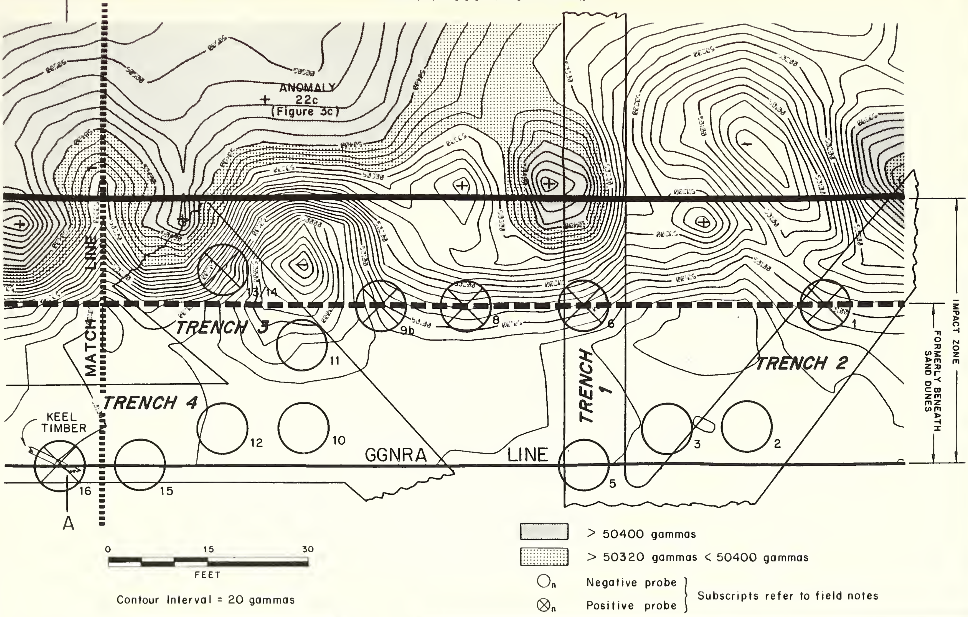


Figure 23b

MAGNETIC CONTOUR MAP AND TEST TRENCHES
APRIL 1988 STUDY AREA

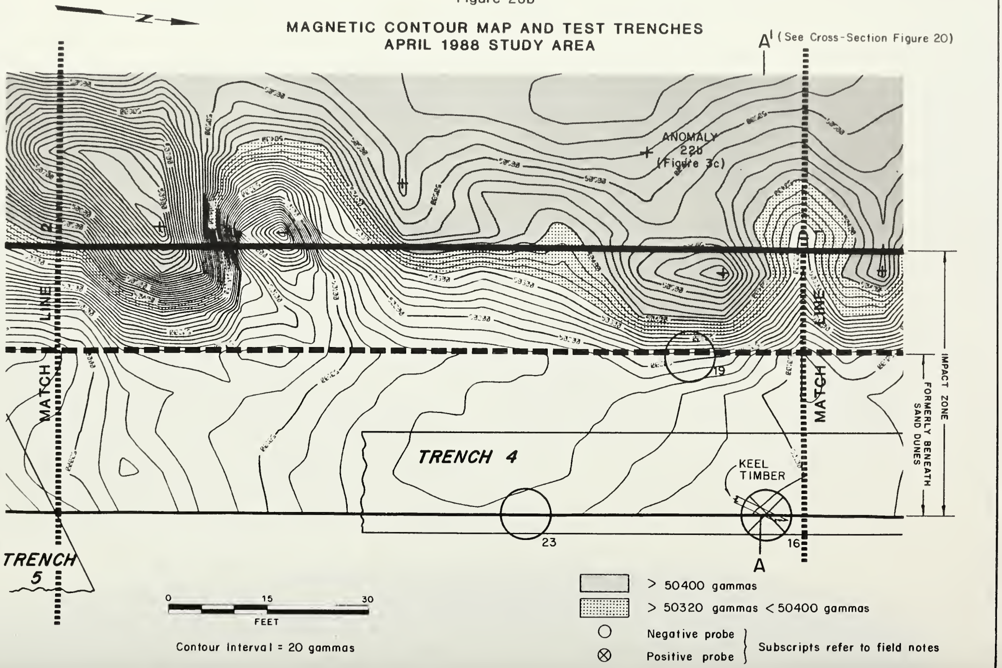
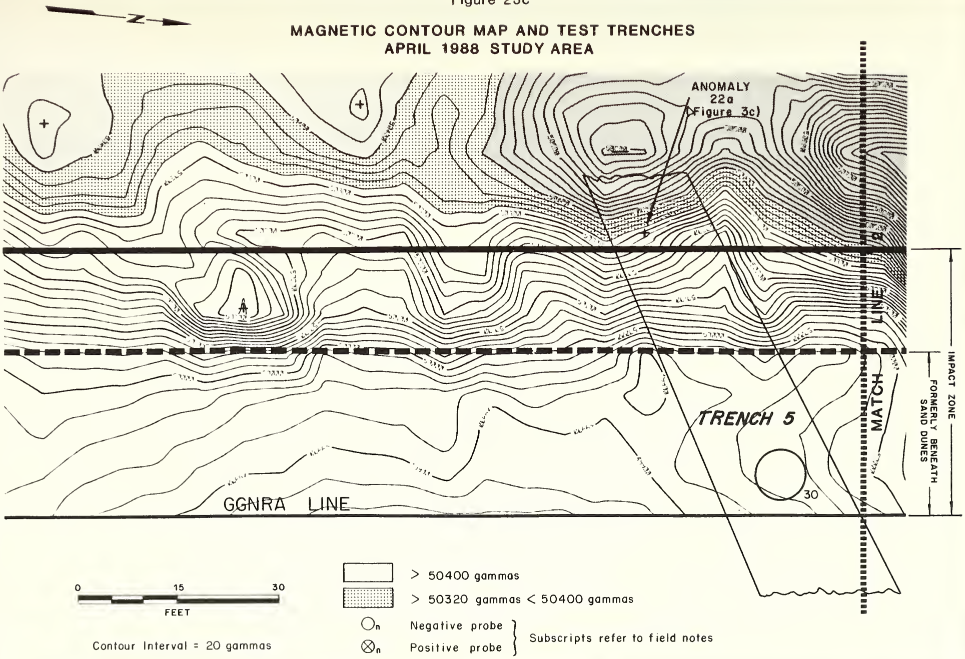

N
A' (See Cross-Section Figure 20)
ANOMALY 22b (Figure 3c)
MATCH LINE 2
MATCH LINE
IMPACT ZONE
FORMERLY BENEATH SAND DUNES
TRENCH 4
TRENCH 5
KEEL TIMBER
19
23
16
A
0
15
30
FEET
Contour Interval = 20 gammas
> 50400 gammas
> 50320 gammas < 50400 gammas
○ Negative probe
⊗ Positive probe
Subscripts refer to field notes

Figure 23c

MAGNETIC CONTOUR MAP AND TEST TRENCHES
APRIL 1988 STUDY AREA



locations of test trenches do not correlate well with anomaly locations. In fact, there are very few well-defined anomalies within the impact zone.

Figure 23 has been shaded to emphasize areas of high magnetic field as was done with figures 3, 18 and 19. In comparing figures 19 and 23, notice that the area of darkest shading (i.e., having the highest magnetic field) had the same general configuration both before and after removal of the riprap and sand dunes from the study area. This fact confirms that the magnetic "plateau" described for the suspected Atlantic wreck site in Chapter V does, indeed, extend nearly to the former dune face, though not beyond. Removal of the riprap from the study area did not significantly alter the location or shape of this plateau. It did, however, alter the locations of anomaly peaks for anomalies 22a, 22b and 22c (compare figures 19 and 23).

We cannot conclude whether the eastern limit of the magnetic plateau is caused by buried wreckage or by buried riprap; however, we can deduce from Figure 23 that no large ferrous mass is present in the area formerly covered by sand dunes, be it riprap or extant sections of wreckage. One small piece of wreckage, a portion of a keel timber, was encountered in Trench 4 (figures 20 and 23b) during testing; however, it did not contain an amount of ferrous metal sufficient to produce an anomaly. The lack of anomalies in the dune area, thus, does not rule out the presence of scattered wreckage but does indicate the absence of large articulated vessel elements which would be likely to contain numerous iron fasteners.

One final observation can be made regarding the magnetic survey results. Beginning approximately at the former slope base (indicated by a heavy dashed line in Figure 23) and progressing westward, there is a marked increase in the magnetic gradient along the entire length of the study area. This pattern indicates that a significant amount of riprap had tumbled down the former slope and become buried in the beach. This supposition was supported by the results of hydraulic probing and by the excavation of test trenches. In both cases, buried riprap was encountered only west of the former slope base.

Hydraulic Probing

A total of 16 locations were probed hydraulically using a 10-foot length of PVC pipe, connected to a hose, as a water jet. The areas where probing was conducted are indicated on Figure 23 by circles. Each circle has a corresponding number referencing both Table 3 and EH&A's field notes. Circles shown with a large "X" at their center are those areas in which solid objects were encountered by the probe.

One can see by a glance at Figure 23 that, with the exception of Probe 16, buried objects were encountered only west of the former slope base. In each of the latter cases, either concrete or gravel was encountered. Probe 16 encountered wood at a depth of 4 feet below the surface. Excavation later revealed this wood to be part of a ship's keel

TABLE 3
RESULTS OF HYDRAULIC PROBING

Probe Number*	Maximum Depth	Results
1	6 inches	rock
2	6 feet	--
3	4 feet	--
5	4 feet	--
6	1 foot	rock
8	1 foot	gravel/rock
9b	4 feet	gravel at 3 feet
10	6 feet	--
11	4 feet	some gravel
12	5 feet	--
13/14	2 feet	gravel
15	5 feet	--
16	6 feet	wood at 4 feet
19	5 feet	--
23	5 feet	--
30	5 feet	--

* Probe numbers reference Figure 23 and field notes.

(described below). Although the locations selected for probing were subsequently determined to be non-anomalous, the results of probing support the contention that anomalies and steep gradients occurring within the impact zone are caused by the presence of buried riprap.

Testing

Five test trenches were excavated in the study area using a D-5 Caterpillar bulldozer. The results of these excavations further support our interpretations of the magnetic contours (Figure 23) and confirm the hydraulic probing results. With the exception of Trench 4, the results from each trench are nearly identical. The only buried objects encountered in the other four trenches were assorted pieces of concrete rubble (riprap) (Figure 24). As was the case with probing, riprap was only encountered west of the former slope base. West of that line, trench depths did not exceed 3 feet, as riprap was encountered near the surface. East of the former slope base, trenches were excavated to greater depths in an attempt to locate anomaly sources believed missed by probing. Maximum trench depths were as follows: Trench 1, 3 feet; Trench 2, 5 feet; Trench 3, 6 feet; Trench 4, 6 feet; and Trench 5, 5 feet.

Trench 4 was the only location where historically significant materials were encountered. Operating at a depth of 4 feet below the surrounding surface, the D-5 bulldozer contacted a section of keel timber from a wooden-hulled vessel (figures 25 and 26). The timber measures 9.5 feet long, 15 inches across and at least 15 inches thick. It has been broken at both ends, and the top face has rotted away making complete measurements, other than width, impossible to obtain. A small wood sample from the timber was submitted by NPS to the University of Arizona's Dendrochronology Laboratory where it was tentatively identified as Douglas fir (Pseudotsuga spp.) which is endemic to the Northwest Coast (Kelly 1988).

Four other artifacts were found in close association with the keel. These include a 4-inch-high, brown glass, stoppered bottle with rectangular base and patent neck; a small section of a cigar-shaped, hollow wooden float, painted red on its exterior (a small hole in the float had been repaired with a white-washed strip of canvas held in place by copper tacks); a corroded iron bolt or drift pin, presumably removed from the keel timber; and a small (3 x 3 x 1 inch) unidentified iron object (heavily corroded). The latter two artifacts, along with two small spikes in the keel timber, were the only ferrous materials encountered in Trench 4. All of the above materials, including the keel timber, occurred at a depth of 4 to 5 feet (Figure 20), suggesting that this level may approximate the high water mark prior to accumulation of the dunes over the area.

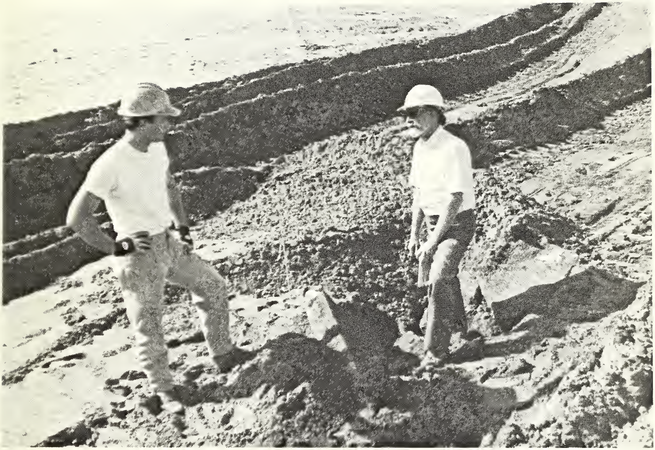


Figure 24. Section of concrete curb-and-gutter encountered in Trench 3 at former location of slope base.

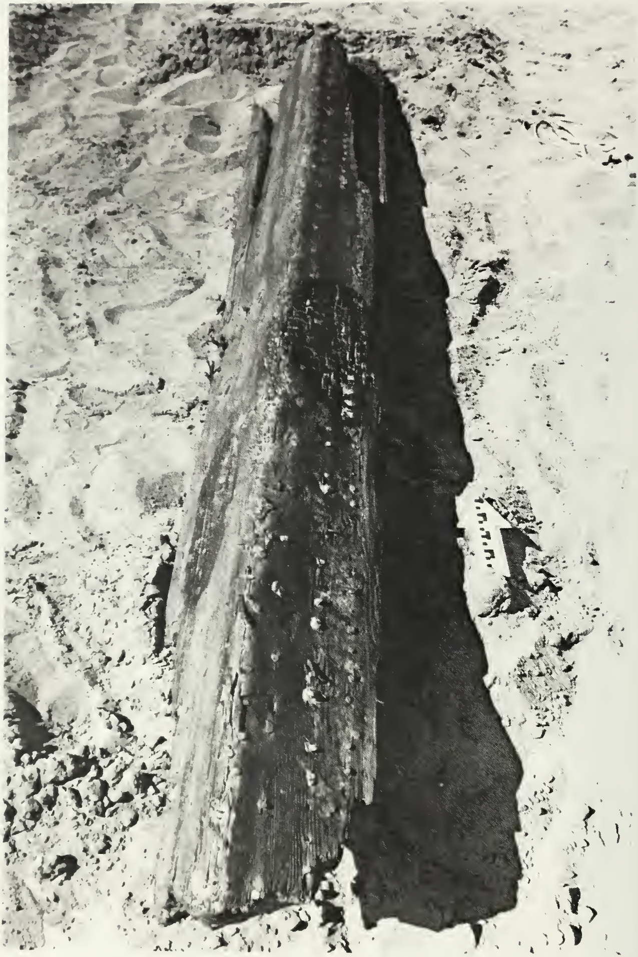


Figure 25. Keel timber from Trench 4. Notice burned areas on both faces and sheathing nails.

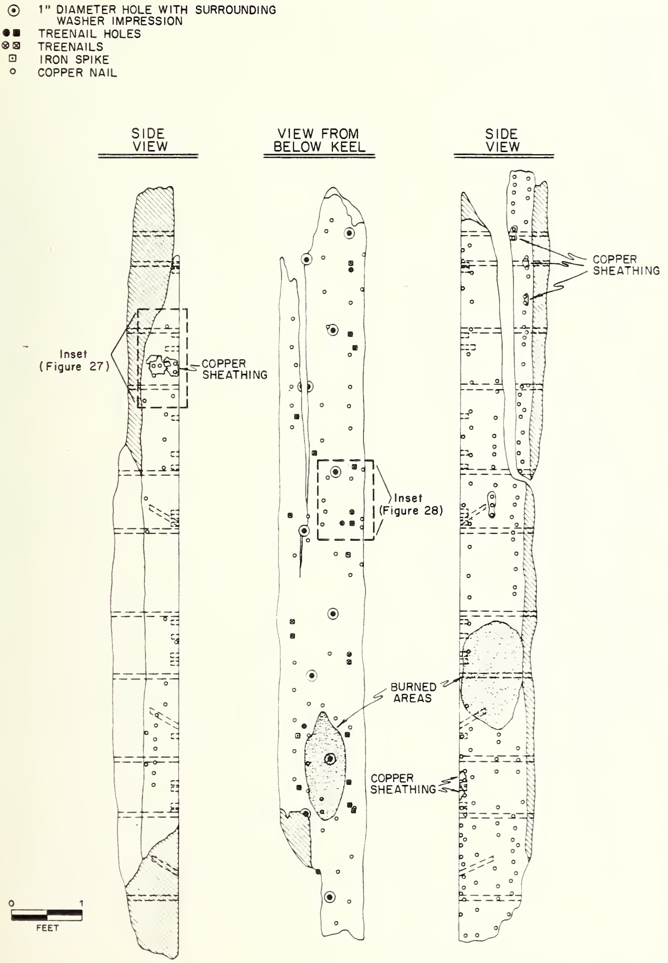


Figure 26. Keel timber, side and bottom views.

Interpretations

The keel timber from Trench 4, and presumably the entire vessel (below the waterline) from which it came, was copper-sheathed at one time; however, the sheathing has been removed from this timber, leaving only rows of copper nails and small fragments of sheathing material (Figure 27). The keel was fastened to the ship's hull by means of 1-inch diameter iron bolts, one of which was found in the sand next to the timber. These bolts were kept from pulling into the bottom of the keel by means of 2-inch diameter washers. The latter were recessed, in order to allow a false keel, or worm board, to sit flush across the bottom of the keel. Evidence that a false keel had once been in place includes both broken-off iron spikes (Figure 26; center) and treenails (trunnels) (Figure 28) in the bottom of the keel.

The false keel, as its alternate name implies, was intended to prolong the life of the keel by protecting it from ship worms (Toredo navalis). It also served to protect iron fittings from corrosion. The false keel on this particular timber had been removed prior to the addition of copper sheathing. One sheathing nail was found driven into the center of a treenail. There was evidence, however, to suggest that sheathing had been added to this section of keel on more than one occasion. The bottom surface of the keel timber, underlying where the false keel had been, was lined with three neat rows of sheathing nails and no empty nail holes, indicating that this surface had only been sheathed one time. The sides of the timber, however, showed evidence, in places, of empty nail holes slightly offset from the in situ sheathing nails, indicating that these surfaces were probably sheathed twice, once before removal of the false keel and once after. As vessels were typically sheathed on an average of every six years (Delgado 1988), it would seem that this timber is either from a vessel which was fairly young when it wrecked or, more likely, that the timber had replaced a damaged section of keel on an older vessel.

The historic record, in combination with the 1987 magnetometer survey results for Ocean Beach, suggests that wreckage from the New Bedford whaling vessel, Atlantic, lies buried in the vicinity of the study area (Figure 19). Prior to testing, it was considered likely that scattered wreckage from the Atlantic would be encountered during this phase of the investigations; however, to the best of our knowledge, the Atlantic's main timbers were of live oak (Quercus spp.), rather than Douglas fir (see Chapter III). Douglas fir does not occur in New England where the Atlantic was built.

The only vessel likely to have been built of Douglas fir and suspected to have wrecked in the vicinity is the Aberdeen. The Aberdeen was built in Aberdeen, Washington, for use in the lumber trade between San Francisco and the Northwest Coast. Wreckage from the Aberdeen washed ashore along a 3-mile stretch of Ocean Beach in 1916 (figures 7 and 17), creating a very noticeable strandline. A group of anomalies, believed to have been caused by strandline wreckage and possibly associated with the Aberdeen, was located by the 1987 magnetometer survey approximately 300 feet north and 75 feet west of where the keel timber was found (see the

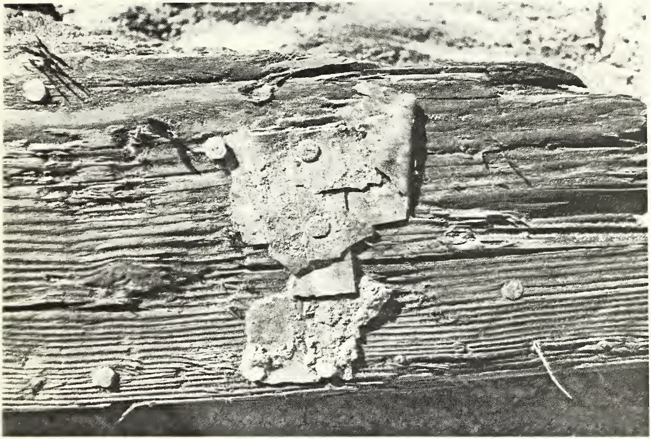


Figure 27. Section of copper sheathing on keel timber (see inset; Figure 26).

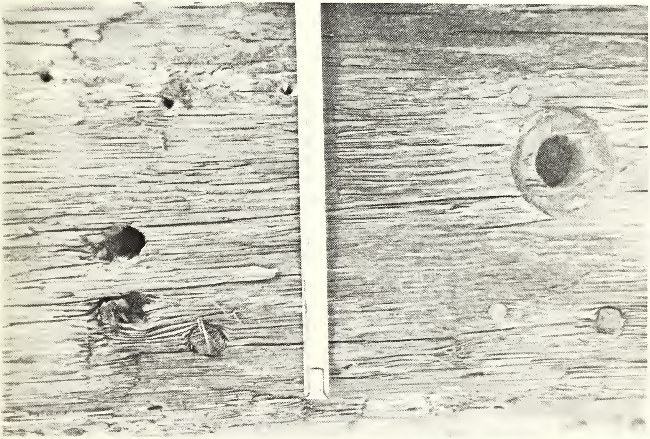


Figure 28. Assorted fasteners on base of keel (see inset; Figure 26).

description of Area C in Chapter V; also figures 3b and 3c). The Aberdeen, however, was apparently not sheathed (Delgado 1988). Unless sheathing was added to the vessel in 1911, when she went into service hauling garbage out of Oakland (which is extremely unlikely), the timber from Trench 4 could not have come from the Aberdeen.

One other bit of evidence to suggest that this timber may not be from the Aberdeen comes from a study of historic shoreline changes along Ocean Beach, conducted by Roger and Nancy Olmsted (1979). Their study goes into great historical detail regarding the development of Ocean Beach and the Great Highway. They point out that the seaward line of the sand dunes, as well as the shoreline, along Ocean Beach was altered significantly during the late nineteenth- and early twentieth-century by the construction of brush fences on the beach and by the planting of dune grass. Both of these measures were designed to accelerate the accretion of sand dunes upon which the present Upper Great Highway was built in 1928-29. By comparing historic coastal and hydrographic survey maps of the Ocean Beach area, they were able to document major changes in shoreline configuration and position which occurred from 1852 to 1929. Along the stretch of beach occupied by the current study area, there was no noticeable change in the position of the high tide line from 1852 to 1899 (Olmsted and Olmsted 1979:12-13). By 1916, when the Aberdeen came ashore, this area was being improved, in anticipation of constructing the Upper Great Highway (ibid.:14). A 1915 aerial view of the beach, showing the vicinity of the study area in the foreground (ibid.:Plate 19), illustrates a well-developed artificial dune line with an unpaved precursor to the Upper Great Highway already in place. It is possible that the dune line shown in this 1915 photograph may have been located west of where the keel timber was found. We cannot be entirely certain, however, as the dune line was extended farther west in 1929 (ibid.:25). We do know that the keel timber was found fully 20 feet east of (beneath) the 1987 base of the sand dunes.

One alternative for the origin of the keel timber is that it may be from a section of the Atlantic which was repaired while the vessel was in service along the Northwest Coast. Prior to 1881, the Atlantic's home port was New Bedford; however, in 1881 she began to sail out of San Francisco. It is likely that any repairs made to her hull during the period from 1881 to 1886, when she wrecked, would have been done using Douglas fir. Any replacement timbers added to Atlantic's hull during this period would have been sheathed only once or twice prior to the breakup of the vessel; whereas, the bulk of Atlantic's hull, which was 30 years old when it wrecked, would have been sheathed as many as five or six times. The proximity of the timber to the area believed to contain the remains of the Atlantic lends support to this interpretation.

A less likely alternative is that the timber comes from an unidentified vessel for which historic references have not been encountered. The staff of the National Maritime Initiative, a division of NPS, has conducted an exhaustive review of literature pertaining to shipwrecks along Ocean Beach; however, no wrecks, other than the King Philip, Atlantic, Reporter and Aberdeen, are known to occur along this section of beach (Delgado 1988). Nevertheless, the 1987 magnetometer survey located a potential wreck site in Area B (Figure 3b) for which we lack adequate documentation in the historic record. We may speculate that the Area B wreck site corresponds to the concentration of large hull sections from the Aberdeen, illustrated in Figure 17 (background); however, until archaeological and/or additional historic data can shed light on its identity, we must assume that wreckage from a fifth vessel may be present.

CHAPTER VII
SUMMARY AND CONCLUSIONS

The ongoing Great Highway/Ocean Beach Seawall Project has been undertaken by the City and County of San Francisco's Clean Water Program in order to prevent further erosion of the sand dunes along Ocean Beach. These dunes overly the West Side Transport, a large wastewater tunnel system, and provide the base for the Upper Great Highway, both of which have been threatened by erosion over the past several years. The seawall will eventually replace the riprap which covers the western face of the dunes along a 2,770-foot section of beach between Noriega and Santiago streets. The section of seawall currently under construction extends 1,800 feet between Ortega and Rivera streets.

Although the seawall will be constructed entirely on city property, a 40-foot wide strip of NPS property, running the entire length of the project area, will be utilized during the construction phase. Concerned that disturbance of the beach within this zone might impact the buried remains of historic shipwrecks, NPS requested that the city contract with a qualified archaeologist to conduct a cultural resources magnetometer survey of the entire beach along the original 2,770-foot project area. Prior research by NPS staff had determined that the remains of at least two historic shipwrecks, the medium clipper, King Philip, and the lumber schooner, Reporter, were located adjacent the proposed seawall. The remains of two additional vessels, the New Bedford whaling bark, Atlantic, and the steam schooner, Aberdeen, were also suspected to be present. Given the fact that at least 26 vessels have come ashore on Ocean Beach (Delgado 1987), it was not considered unreasonable that wreckage from other vessels may also be present.

During the fall of 1987, archaeologists from EH&A conducted a magnetometer survey of the originally proposed 2,770-foot project area. The goal of this study was to identify and delineate areas which might contain the buried remains of historic shipwrecks, so that any such sites may be properly managed and protected during construction of the seawall. The first step toward identifying areas of potential significance was the characterization of magnetic anomaly patterns expected to result from buried wreck sites. Based upon Delgado and Murphy's (1984) classification of environmentally exposed shipwrecks, a preliminary predictive model was developed which describes the expected anomaly patterns for three distinctive types of wreck site: buoyant hull, buoyant hull fracture, and buoyant structure sites. Buoyant hull sites are those, such as the King Philip, in which a ship comes ashore and settles into the sand, relatively intact. Buoyant hull fracture sites, for example, the Atlantic and Reporter wreck sites, occur when the hull of a ship comes ashore intact, but breaks apart on the beach and is dispersed by the surf. Buoyant structure sites form when a ship breaks apart offshore and washes onto the beach in pieces, as did the Aberdeen. This model was then used, in combination with historic documentation of known and suspected shipwrecks within the project area, as a guide in the interpretation of the magnetometer survey data.

The data obtained from the magnetometer survey was computerized and reproduced as a magnetic contour map. This map was interpreted based upon the predictive model developed previously for wreck site patterning. As a result of having conducted this survey, the remains of King Philip and Reporter have been magnetically verified, as have the possible remains of two additional vessels, one of which may be the Atlantic. A fifth area has also been identified which may contain the remains of strandline wreckage associated with the Aberdeen. Based upon the locations of these known and suspected wreck sites, recommendations were made for archaeological verification of 15 specific anomalies occurring adjacent the 40-foot-wide zone of construction impacts. Within the impact zone, it was not possible to distinguish potentially significant anomalies from those caused by magnetic materials occurring in the riprap. A draft report was prepared by EH&A, describing the results of the magnetometer survey, as well as our recommendations for further archaeological investigations. The draft report (chapters II through V of this document) was submitted to the Clean Water Program in December of 1987 and subsequently reviewed by NPS.

In the spring of 1988, a contract was let by the City of San Francisco for construction of the first section of seawall, extending 1,800 feet between Ortega and Rivera streets. Thirteen of the fifteen anomalies initially recommended by EH&A for testing are located along this area. NPS concurred with EH&A's recommendations for anomalies 22a, 22b and 22c and required that the city contract for additional archaeological investigations in their vicinity, prior to construction. These three anomalies, located in the area where the Atlantic is believed to have wrecked, are considered to have the greatest potential, of the original 15 anomalies recommended, for being associated with buried wreckage. Additional investigations required by NPS include a second magnetometer survey of a small area surrounding the three anomalies and archaeological test excavations of potentially significant anomalies identified by this survey. This work was to be conducted following removal of riprap and sand dunes from the area. The purpose was to determine the eastward extent of anomalies potentially associated with the Atlantic.

In April of 1988, EH&A returned to Ocean Beach to conduct the additional investigations required by NPS. Following removal of the riprap and underlying sand dunes from the area surrounding anomalies 22a, 22b and 22c, a magnetometer survey was conducted of a 360-foot by 72-foot area centering on these anomalies (Figure 19). This survey was followed immediately by archaeological test excavations in conjunction with hydraulic probing. A total of five test trenches were mechanically excavated within the impact zone, using a D-5 bulldozer. Only one trench contained evidence of a wreck site. A 9.5-foot section of ship's keel from a copper-sheathed vessel was encountered in Trench 4 at a depth of 4 to 5 feet below the surface. This keel timber has been tentatively identified as a portion of the Atlantic.

The results of investigations conducted on anomalies 22a, 22b and 22c indicate a low probability for the presence of articulated wreckage within the zone to be impacted by seawall construction. Buried wreckage from Atlantic may be the cause of the magnetic plateau which occurs west of the impact zone in Figure 23; however, the primary source of magnetic anomalies and high magnetic gradients within the impact zone is buried riprap. Buried riprap occurs only west of the former base of the dune slope. The area formerly covered by sand dunes is void of anomaly patterns which could be interpreted as potentially significant. Nevertheless, scattered wreckage, as well as other artifactual debris, does occur in the area formerly covered by sand dunes, as evidenced by the section of ship's keel and associated materials encountered during testing.

Based upon the lack of a magnetic anomaly associated with the keel timber, it is apparent that scattered, disarticulated wreckage is not always detectable by magnetic survey techniques. Although small, isolated elements of a shipwreck cannot generally be regarded as significant, in and of themselves, they may provide important clues toward identifying the sources of anomaly patterns located farther out on the beach and should be well-documented, with this goal in mind, whenever encountered. The most effective means of searching for isolated vessel elements within the impact zone is by means of construction monitoring, as they cannot be relied upon to produce anomalies which are distinguishable from those of buried riprap material, if they produce anomalies at all.

Although no articulated sections of wreckage were encountered within the impact zone in the vicinity of anomalies 22a, 22b and 22c, the same cannot necessarily be said for the vicinity of the suspected wreck site in Area B nor for the area of the King Philip and Reporter wreck sites, all three of which are located north of the seawall segment currently under construction. In Area B, for example, the magnetic effects of the riprap are the most severe observed. As a result, we cannot distinguish how far inland the suspected wreck pattern of Area B extends. In Area A, a portion of the beach underlying a large sandpile remains unsurveyed.

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SUSPECTED
ATLANTIC
WRECK
SITE
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